United States Court of Appeals
for the Second Circuit

EXHIBITS

UNITED STATES
DEPARTMENT OF THE INTERIOR

76-6122

B

FINAL
ENVIRONMENTAL STATEMENT

VOLUME 1 OF 3

UNITED STATES COURT OF APPEALS
FILED
SEP 14 1976
A. DANIEL FUSARO, CLERK
SECOND CIRCUIT

PROPOSED
INCREASE IN OIL AND GAS LEASING
ON THE OUTER CONTINENTAL SHELF

FES 75 -

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Prepared by the
BUREAU OF LAND MANAGEMENT

Curt Berklund
Director

Summary

( ) Draft (X) Final Environmental Statement

Department of the Interior, Bureau of Land Management
Chief, Division of Minerals Environmental Assessment
Washington, D. C.

1. Proposed Increase in Oil and Gas Leasing on the Outer Continental Shelf

   (X) Administrative ( ) Legislative Action

2. It is proposed to accelerate Outer Continental Shelf oil and gas leasing in the years 1975 through 1978 by conducting six lease sales each year, including lease sales in some or all frontier areas by 1978. Many of these areas have little or no history of OCS oil and gas development. The possible environmental impacts of proceeding in such a manner are examined, and the relative risks of proceeding with development in each of the 17 OCS areas are analyzed.

3. Alternatives considered:

   A. Defer Action or Take No Action
   B. Reduce Rate of OCS Leasing Below the Historical Level
   C. Halt OCS Leasing
   D. Postpone Decisions About the OCS Until Comprehensive National Energy Plan is Developed
   E. Energy Conservation
   F. Alternative Fuel Sources and Their Environmental Impacts
   G. Leasing at a Slower Rate
   H. Leasing Frontier Areas in a Different Sequence
   I. Two-Stage Versus One-Stage OCS Development
   J. Alternative OCS Exploratory Program
   K. Alternative Lease Bidding System
   L. Alternative Management and Supervisory System

4. Comments have been received from the following Federal agencies and States:

   Federal Agencies

   Federal Energy Administration

   Federal Power Commission

   Environmental Protection Agency

4. Continued

Department of Defense
  Assistant Secretary's Office
  U. S. Army Corps of Engineers

Department of Transportation
  U. S. Coast Guard

Energy Research and Development Administration

Department of Commerce
  Assistant Secretary for Science and Technology
  National Oceanic and Atmospheric Administration -
    National Marine Fisheries Service

Department of the Interior
  Bureau of Mines
  Bureau of Outdoor Recreation
  National Park Service
  U. S. Geological Survey
  Fish and Wildlife Service

States

State of Alaska

State of California

State of Delaware

State of Florida

State of Georgia

State of Maryland

State of Massachusetts

State of New Hampshire

State of New Jersey

State of New York

State of Oregon

State of Texas

State of Virginia

5. Final statement made available to the Council on Environmental Quality and the public on July 7, 1975.

TABLE OF CONTENTS

VOLUME I

Page

I. DESCRIPTION OF THE PROPOSED ACTION 1
- A. Statement of the Proposed Action 1
  - 1. Purpose of the Proposed Action 1
  - 2. Scope of the Proposed Action 13
- B. Proposed Oil and Gas Resource Management and Supervision System 21
- C. Description of OCS Oil and Gas Operations 33
  - 1. Oil and Gas Operations 33
  - 2. Offshore Oil and Gas Development Technology 78
- D. Other Management and Supervisory Aspects of the Program. 94
  - 1. Management Requirements Before Onset of OCS Operations 94
  - 2. Proposed Supervisory Procedures for OCS Resource Development 104
  - 3. Related Management and Supervisory Authorities . . . 128
  - 4. OCS Research Management Advisory Board 134
  - 5. Environmental Data Gathering Programs 135
  - 6. Requirements for OCS Facilities and Equipment . . . 153

II. DESCRIPTION OF THE ENVIRONMENT 155
- A. Description of the Offshore Environment 155
  - 1. Atlantic Region 155
    - a. Geology 155
    - b. Climate 180
    - c. Physical Oceanography 185
    - d. The Biological Environment 197
    - e. Natural Phenomena Unique to Area with Potential To Cause or Contribute to Environmental Impacts of Proposed Action 217
  - 2. Gulf of Mexico Region 220
    - a. Geology 220
    - b. Climate 236
    - c. Physical Oceanography 246
    - d. The Biological Environment 253
    - e. Natural Phenomena Unique to Area with Potential to Cause or Contribute to Environmental Impacts of Proposed Action 268
  - 3. Pacific Region 271
    - a. Geology 271
    - b. Climate 300
    - c. Physical Oceanography 308
    - d. The Biological Environment 319
    - e. Natural Phenomena Unique to Area with Potential to Cause or Contribute to Environmental Impacts of Proposed Action 336

Page

4. Alaska Region 338
   a. Geology 338
   b. Climate 371
   c. Physical Oceanography 379
   d. The Biological Environment 389
   e. Natural Phenomena Unique to Area with Potential to Cause or Contribute to Environmental Impacts of Proposed Action 413

B. Description of Nearshore and Coastal Zone Environment . . 415
1. Atlantic Region 415
   a. Geology 415
   b. Biological Environment and Communities of the Coastal Zone 415
   c. Resources of the Coastal Zone 431
   d. Existing Environmental Quality Problems in Coastal Zone 501
2. Gulf of Mexico Region 513
   a. Geology 513
   b. Biological Environment and Communities of the Coastal Zone 513
   c. Resources of the Coastal Zone 533
   d. Existing Environmental Quality Problems in Coastal Zone 577
3. Pacific Coast Region 588
   a. Geology 588
   b. Biological Environment and Communities of the Coastal Zone 588
   c. Resources of the Coastal Zone 595
   d. Existing Environmental Quality Problems in Coastal Zone 639
4. Alaska Region 657
   a. Geology 657
   b. Biological Environment and Communities of the Coastal Zone 658
   c. Resources of the Coastal Zone 667
   d. Existing Environmental Quality Problems in Coastal Zone 694

C. Description of Significant and Potential Vulnerable Resources 699
1. North Atlantic. 700
2. Mid-Atlantic. 703
3. South Atlantic. 706
4. Eastern and Central Gulf of Mexico. 711
5. Western Gulf of Mexico. 717
6. Southern California Borderland. 722

Page

7. Santa Barbara 727
8. Northern and Central California 731
9. Washington-Oregon 734
10. Gulf of Alaska. 743
11. Cook Inlet. 749
12. Southern Aleutian Shelf (Kodiak). 752
13. Bristol Bay, St. George and Navarin Basins. . . . 757
14. Bering Sea (Norton Basin) 767
15. Chukchi and Beaufort Seas 771

D. Endangered and Threatened Fish and Wildlife 776

TABLE OF CONTENTS

VOLUME II

III. ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION 1
- A. Introduction and Methodological Overview. 1
- B. The Sources of Impact Generating Effluents. 15
  - 1. General Environmental Impacts of OCS Petroleum Development Operations. 15
  - 2. Impacts Generated by Routine OCS Oil and Gas Production Activities Which are Economically Unavoidable Under Existing Technology and Regulatory Practices. 16
    - a. Discharge of Cleaned Drilling Muds and Drill Cuttings. 16
    - b. Discharge of Produced Formation Waters. 18
    - c. Disruption of Sea Floor and Resuspension of Sediments During Pipeline Burial. 21
    - d. The Physical Presence of Platforms, Boats, Barges and Ancillary Onshore Facilities 24
  - 3. Impacts Resulting from Accidents. 26
    - a. Natural Gas Leaks Associated with Blowouts. . . 27
    - b. Oil Spills Greater than 50 Barrels in Size. . . 29
  - 4. Probabilities of Oil Spills Larger than 1,000 Barrels - The MIT Analysis. 56
    - a. Platforms and Pipelines 57
    - b. Tankers 58
    - c. Total Number and Volume of OCS Oil Spills . . . 58
  - 5. Accidental Deaths and Injuries on OCS Industry Structures and Vessels. 60
- C. Natural Phenomena in Each OCS Area and Their Impact Generating Potential. 61
  - 1. Exploration Phase 63
  - 2. Production Phase. 65
  - 3. Storage Phase 69
  - 4. Transportation Phase. 72
    - a. Pipelines 74
    - b. Tankers 75
  - 5. Summary 78
  - 6. Area by Area Evaluation of Natural Phenomena Oil Spill Risks 86
- D. Major Oil Spills and the Marine Environment 100
  - 1. Generic Description of the Fate of Spilled Oil. . . . 100
  - 2. The Santa Barbara Oil Spill 105
- E. Proximity Analysis. 109
- F. Generic Impacts 139
  - 1. Introduction. 139
  - 2. Impacts on Plankton 146

3. Impacts on Fish 150
4. Impact on Benthic Marine Life 152
5. Impact on Birds 155
6. Impact on Mammals 157
7. Impact on Plants. 158
8. Impacts on Unique and Highly Valued Areas 158
9. Impacts on Commercial and Sport Fisheries 163
    a. Removal of the Sea Floor From Use 163
    b. Creation of Obstructions. 164
    c. Contamination of Fish by Spilled Oil. 165
    d. Reduction of Fishing Effort Due to Spilled Oil 166
    e. Removal of Onshore Sites Considered for Aquaculture 166
    f. Sport Fishing 167
10. Impacts on Recreational Values. 169
11. Impacts on Endangered and Threatened Species. . . 172

G. Impacts Not Specific to Region. 180
1. Socio-economic Impacts. 181
    a. Exploration Phase 181
    b. Drilling and Production Phase 189
    c. Transportation of Crude Oil and Gas 190
    d. Processing of Oil and Gas 194
    e. Two studies of Costs and Benefits to Governments in Coastal States 209
2. Impacts on Aesthetic and Scenic Values. 215
3. Impact on Air Quality 217
4. Impact on Water Quality 219
5. Historical or Archeological Sites and Objects . . 222
6. Impact on Ship Traffic and Navigation 224

H. Resources Summary and Oil Spill Risk Summary. 231
I. Cumulative Impacts. 243

IV. MITIGATING MEASURES. 250
A. Increasing Financial Incentives to Lessees. 250
B. Regulations 252
C. Facilitate Research and Diffusion of Technical Innovation. 255
D. "Fine Tuning" for Special Circumstances 256
E. Helping to Coordinate Private Party Development Plans 259
F. The Costs and Benefits of Mitigation. 260

V. UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

A. Effects on Marine Organisms 262
B. Wetlands and Beaches. 266
C. Deterioration of Air Quality. 267
D. Deterioration of Salt Water 269
1. Operational Discharges. 269

2. Accidental Discharges. 270
E. Interference with Commercial Fishing Operations. . . 270
F. Interference with Ship Navigation. 271
G. Damage to Historical and Archeological Sites, Structures and Objects 272
H. Interference with Recreation Activities. 273
I. Degradation of Aesthetic Values. 274
J. Preclusion of other uses of the Land 274

VI. RELATIONSHIP BETWEEN LOCAL SHORT-TERM USE AND MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY 276

VII. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES . 279
A. Mineral Resources. 279
B. Land Resources 280
C. Biotic Resources 281

VIII. ALTERNATIVES TO THE PROPOSED ACTION 283
A. Defer Action or Take No Action 286
  1. Description. 286
  2. Environmental Impact 287
B. Reduce the Rate of OCS Leasing Below the Historical Level. 288
  1. Description. 288
  2. Environmental Impacts. 288
C. Halt OCS Leasing 290
  1. Description. 290
  2. Environmental Impacts. 290
D. Postpone Decisions About the OCS Until a Comprehensive National Energy Play is Developed. . . 292
  1. Description. 292
  2. Environmental Impacts. 293
E. Energy Conservation. 295
F. Environmental Impacts Associated with Alternative Fuel Sources 301
  Increased Oil Imports. 302
  Coal. 303
  Nuclear Energy 309
  Oil Shale. 312
  Increased Domestic Onshore Oil Production. 316
  Increased Hydroelectric Power. 318
  Increased Pipeline Imports of Natural Gas. 320
  Increased Liquefied Natural Gas (LNG) Imports. . . . 324
  Solar Energy 327
  Geothermal Energy Production 331
  Combination of Some or All of the Above. 334

G. Leasing at a Slower Rate. 335
H. Leasing Frontier Areas in a Different Sequence. 341
I. Two-Stage Versus One-Stage OCS Development. 350
J. Alternate OCS Exploratory Programs. 353
  1. Description. 353
    a. Special Limited Leasing in Frontier Areas with Requirements for Prompt Unitized Exploration. . 353
    b. Leases for Exploration Only. 353
    c. Federal Exploratory Drilling Program 354
    d. Off Structure Stratigraphic Drilling 355
K. Alternative Lease Bidding Systems 357
  1. Description. 357
    a. Royalty Bidding with Fixed Bonus 357
    b. Net Profit Sharing 359
    c. Deferred Bonuses 361
L. Alternative Management and Supervisory Systems. 363
  1. Description. 363
    a. Place All Management and Supervisory Functions Under one Agency 363
    b. Divide Management and Supervisory Functions Between or Among Agencies. 364
    c. Consolidate Present Leasing Functions of BLM and Present Supervisory Functions of USGS Under One Bureau in Department of the Interior 365
    d. Same System as Proposed Action But with Increased Funding and/or Personnel 365
    e. Promulgation of OCS Orders for Frontier Areas. . 366

IX. CONSULTATION AND COORDINATION WITH OTHERS. 367
  A. Preparation of the Draft Environmental Statement. . . . 367
    1. Federal Participation 367
    2. State Participation 367
  B. Coordination and Review of the Draft Statement Leading to Preparation of the Final Statement 367
    1. Federal Agencies. 367
      a. Federal Energy Administration 368
      b. Federal Power Commission. 374
      c. Environmental Protection Agency 379
      d. Department of Defense 409
      e. Department of Transportation. 422
      f. Energy Research and Development Administration. 424
      g. Department of Commerce. 427
      h. Department of Interior. 470
         Bureau of Mines 470
         Bureau of Outdoor Recreation. 491
         National Park Service 496
         U.S. Geological Survey. 499
         Fish and Wildlife Service 521
    2. States. 555

  - a. Alaska. 555
  - b. California. 626
  - c. Delaware. 711
  - d. Florida 718
  - e. Georgia 735
  - f. Maryland. 753
  - g. Massachusetts 780
  - h. Mississippi 875
  - i. New Hampshire 885
  - j. New Jersey. 897
  - k. New York. 937
  - l. Oregon. 964
  - m. Texas 972
  - n. Virginia. 979

3. Public Hearing Testimony and Record 1008
4. Other Public Comments 1018

TABLE OF CONTENTS

VOLUME III

Attachments

Attachment A - OCS Regulations. 2

Attachment B - Operating Orders - Gulf of Mexico and Pacific. . 28

Attachment C - Proposed Operating Orders - Gulf of Alaska . . . 152

Attachment D - OCS Research Management Advisory Board Charter . 175

Attachment E - Geological Survey Response to Energy Under the Oceans. 181

Attachment F - Report on the Responses Received in Reply to the Request for Comments on Potential Future OCS Oil and Gas Leasing 212

Attachment G - Full Text Comments on Proposal from State of Alaska 262

Attachment H - Full Text of Comments on Proposal by Southern California Council of Local Governments. 413

Attachment I - Proposed Regulations Regarding Conduct of Geological and Geophysical Explorations of the OCS. . . . 897

Attachment J - List of References 903

Attachment K - Glossary 929

Note:

This final environmental statement has been prepared pursuant to section 102(@) (c) of the National Environmental Policy Act of 1969.

The regulations to which reference is made throughout this environmental statement are 30 CFR Part 250 and 43 CFR 3300, and Geological Survey OCS Orders Nos. 1 through 12 - Gulf of Mexico, and OCS Orders Nos. 1 through 10 - Pacific. The OCS Orders for the Gulf of Mexico and Pacific have been appended to this statement, as have the proposed operating orders for the Gulf of Alaska. Although too bulky to append in entirety, pertinent portions of the relevant CFR's are appended. The entire CFR's may be obtained from the United States Department of the Interior.

I. DESCRIPTION OF THE PROPOSED ACTION

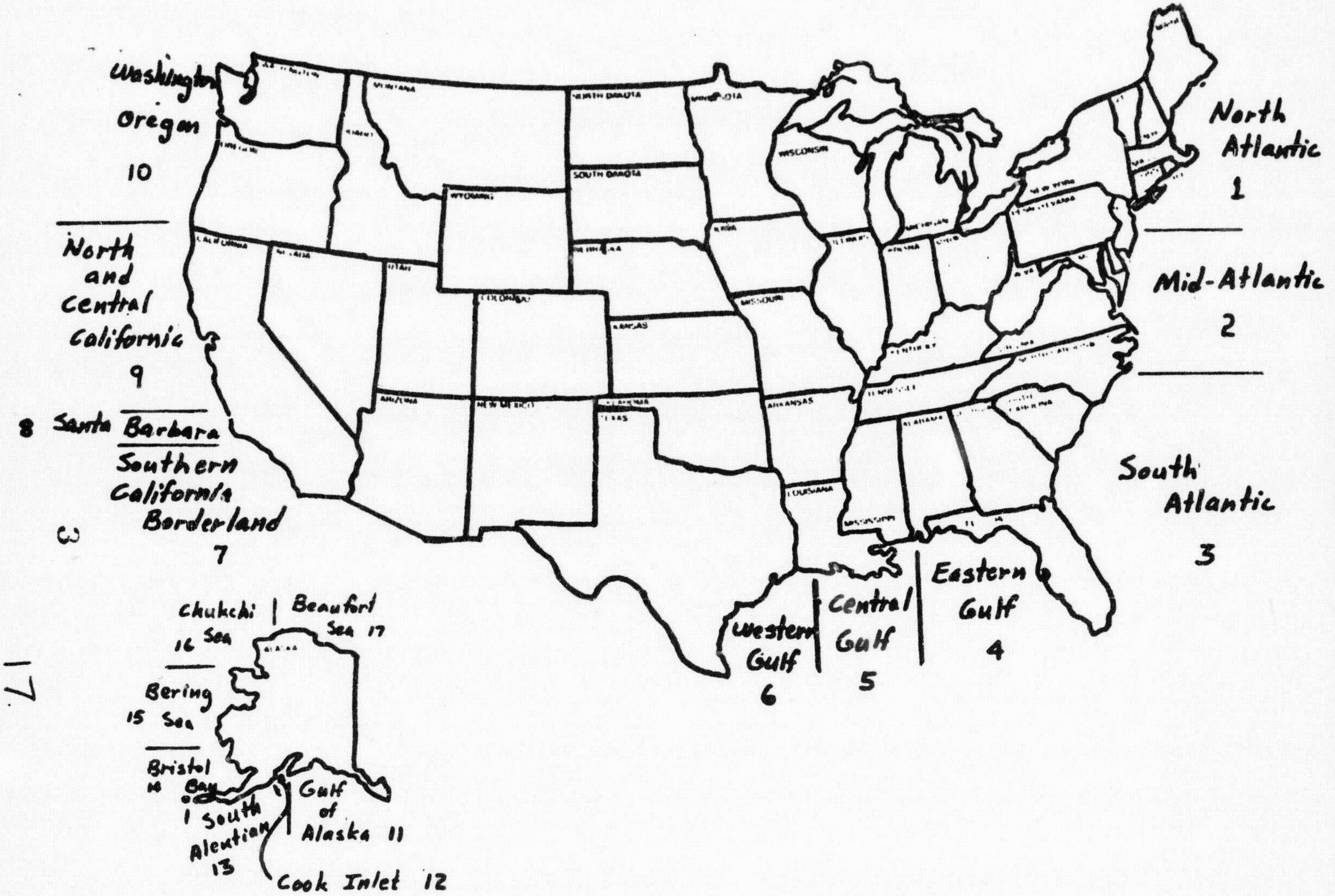
A. Statement of the Proposed Action

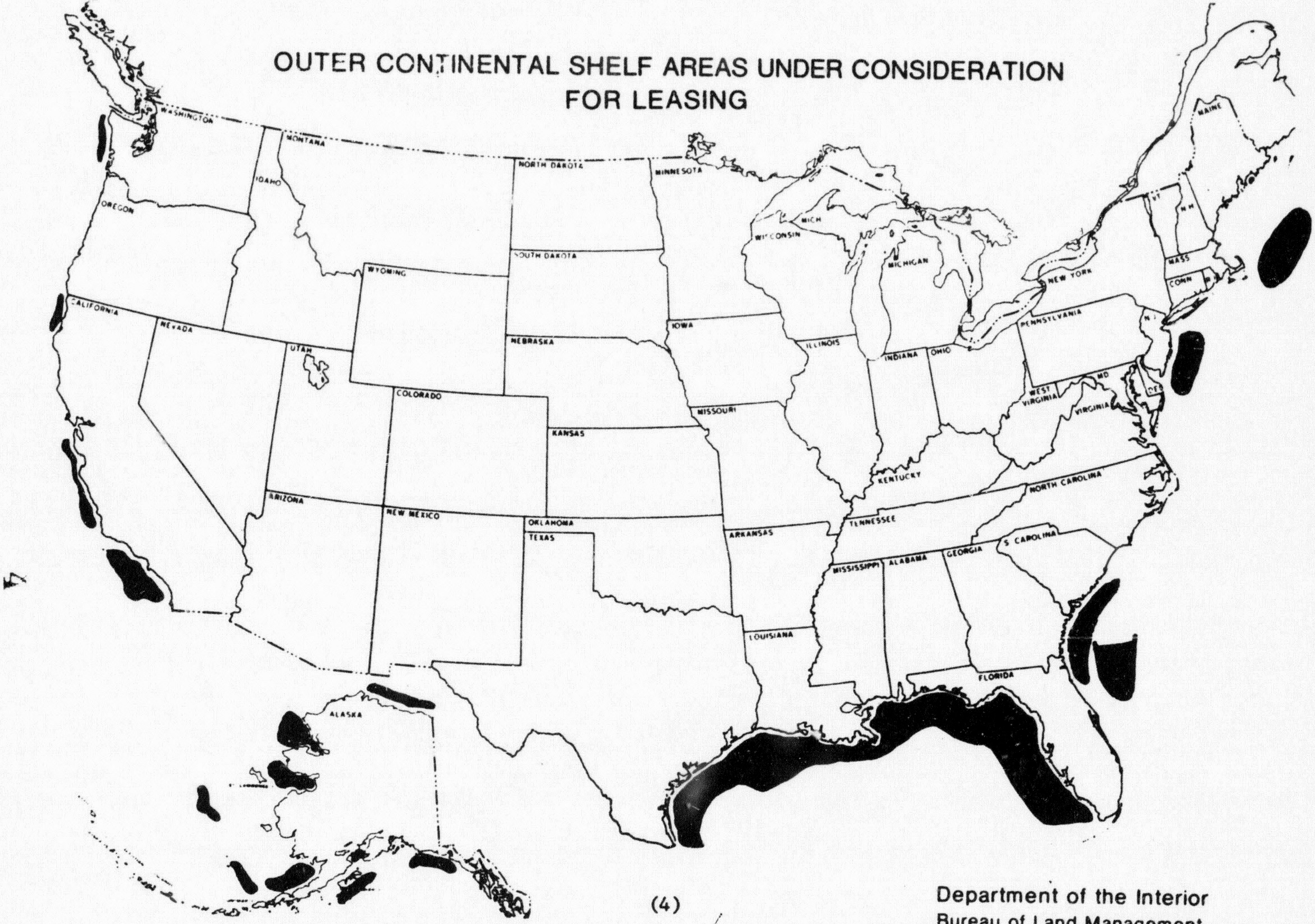
1. Purpose of the Proposed Action

The action which is the subject of this final environmental impact statement is a proposed program to accelerate Outer Continental Shelf (OCS) oil and gas leasing by the Federal Government in calendar year 1975 and succeeding years. This acceleration would occur nationwide according to a revised proposed OCS planning schedule of six proposed lease sales for 1975 and six possible lease sales per year for the period 1976-1978, including some or all frontier areas by the end of 1978. This definition of the proposed action is a modification of the definition given in the draft environmental statement on accelerated OCS leasing. A tentative planning schedule was published in November 1974, after the draft statement had been released, which further specified details of a possible leasing schedule through 1978. An updated planning schedule was published in June 1975 (Figure 1). The regions used in the schedule, both geographic and geologic, are depicted in figures following Figure 1. This schedule incorporates the sales to be considered in 1975, which were discussed in the draft statement. Comments received from the public, as well as further internal review, have persuaded the Department to drop specific acreage figures as planning targets. It now appears more feasible to plan the program in terms of possible areas to be open for leasing and a certain number of sales per year. Hence the target figure of "ten million acres" to be leased in 1975 has been dropped as an element of the present proposal.

EDITOR'S NOTE

Pages 2 were missing at time of filming. If, and when obtained, a corrected fiche will be forwarded to you.

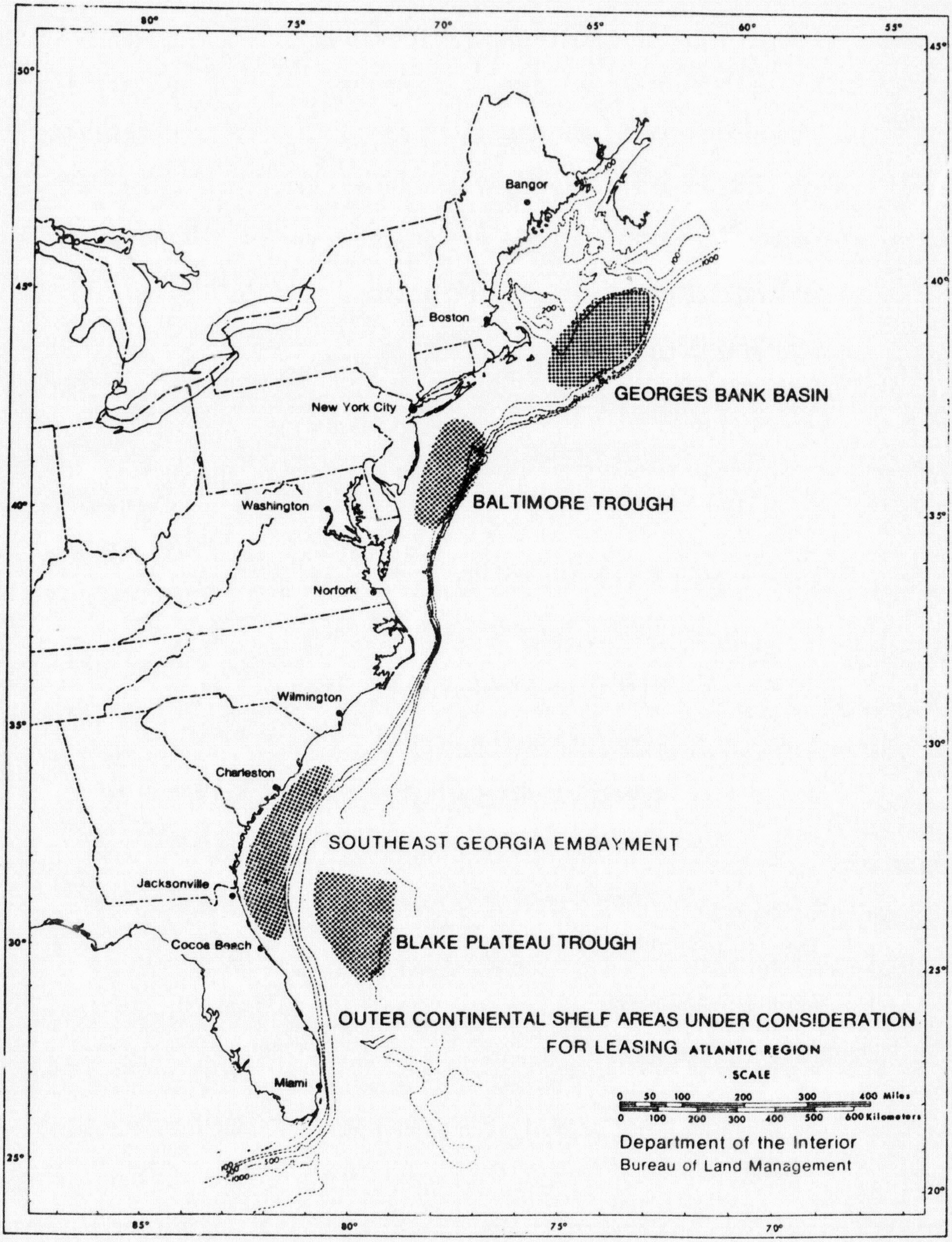

Washington
Oregon
10
North and Central California
9
8 Santa Barbara
Southern California Borderland
7
North Atlantic
1
Mid-Atlantic
2
South Atlantic
3
Eastern Gulf
4
Central Gulf
5
Western Gulf
6
Chukchi Sea
16
Beaufort Sea 17
Bering Sea
15
Bristol Bay
14
South Aleutian
13
Gulf of Alaska 11
Cook Inlet 12



OUTER CONTINENTAL SHELF AREAS UNDER CONSIDERATION FOR LEASING

WASHINGTON
OREGON
CALIFORNIA
IDAHO
NEVADA
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
MICH
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
S CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
MD
DEL
NJ
PENNSYLVANIA
NEW YORK
VT
NH
MAINE
MASS
CONN
RI
ALASKA

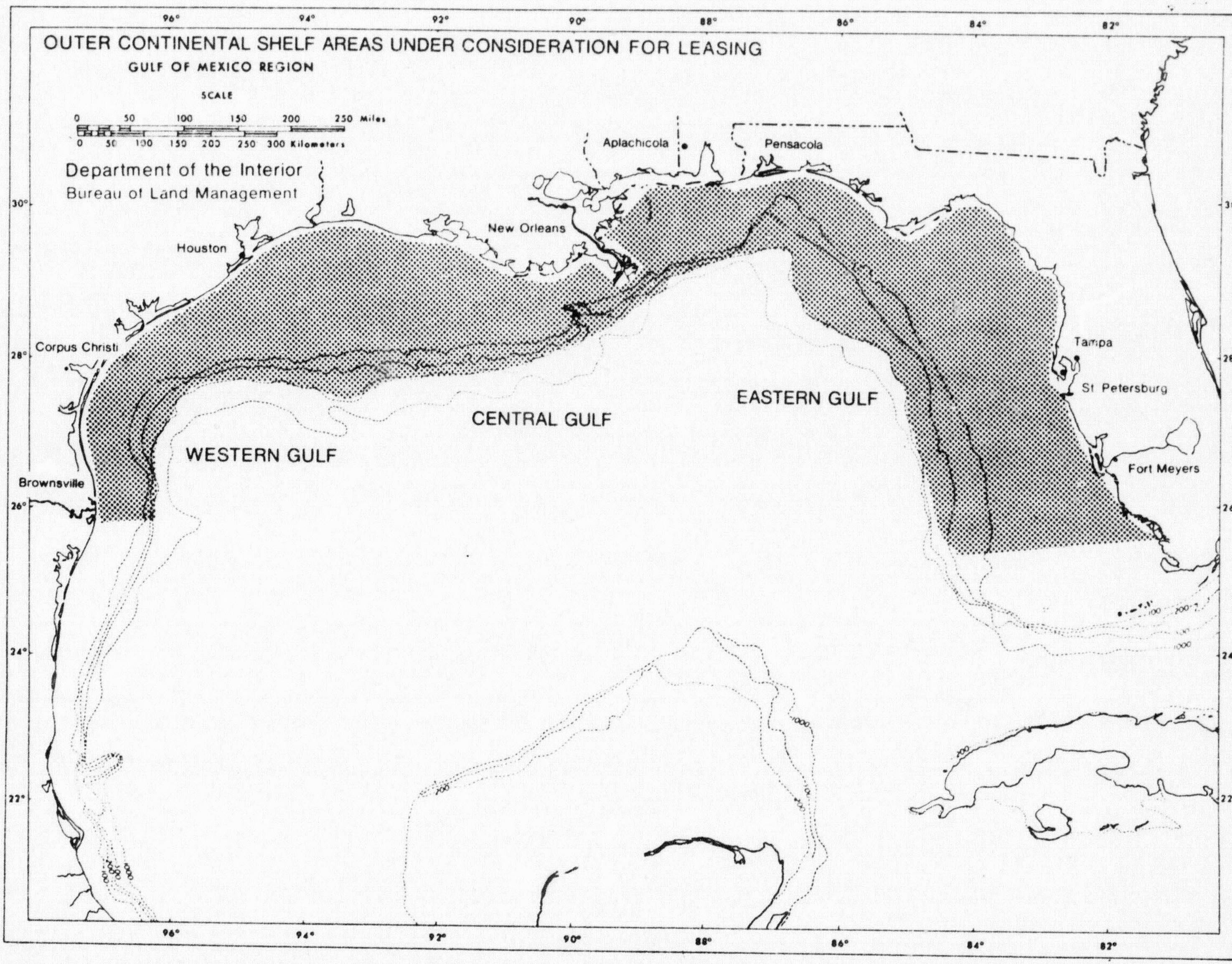
Department of the Interior
Bureau of Land Management



OUTER CONTINENTAL SHELF AREAS UNDER CONSIDERATION FOR LEASING ATLANTIC REGION

Department of the Interior
Bureau of Land Management

80°
75°
70°
65°
60°
55°
45°
40°
35°
30°
25°
20°
50°
85°
Bangor
Boston
New York City
Washington
Norfolk
Wilmington
Charleston
Jacksonville
Cocoa Beach
Miami
GEORGES BANK BASIN
BALTIMORE TROUGH
SOUTHEAST GEORGIA EMBAYMENT
BLAKE PLATEAU TROUGH
100
200
500
1000
SCALE
0 50 100 200 300 400 Miles
0 100 200 300 400 500 600 Kilometers

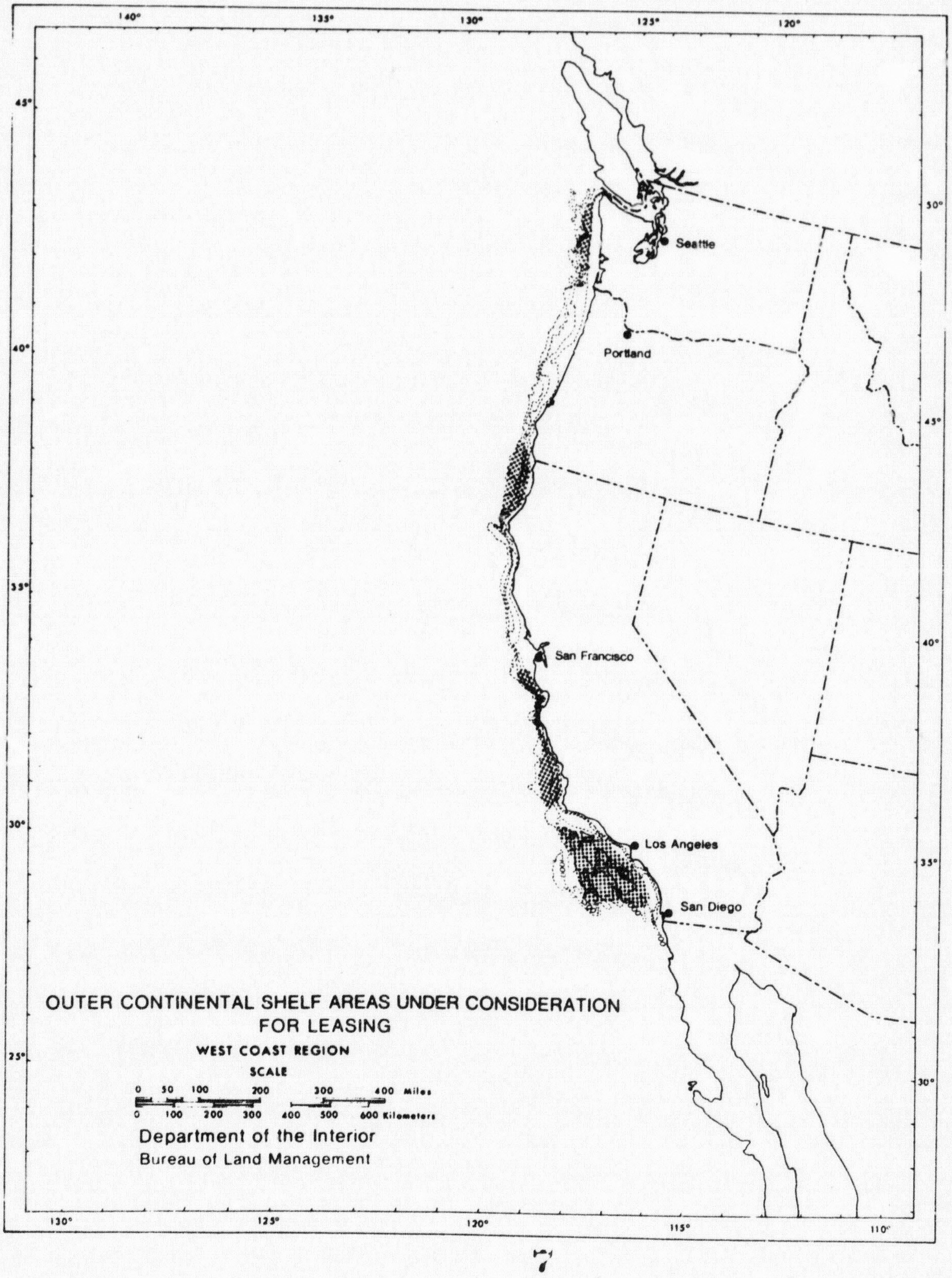


OUTER CONTINENTAL SHELF AREAS UNDER CONSIDERATION FOR LEASING

GULF OF MEXICO REGION

Department of the Interior
Bureau of Land Management

SCALE
0 50 100 150 200 250 Miles
0 50 100 150 200 250 300 Kilometers
96°
94°
92°
90°
88°
86°
84°
82°
30°
28°
26°
24°
22°
Aplachicola
Pensacola
New Orleans
Houston
Corpus Christi
Brownsville
Tampa
St. Petersburg
Fort Meyers
EASTERN GULF
CENTRAL GULF
WESTERN GULF
100
200
1000

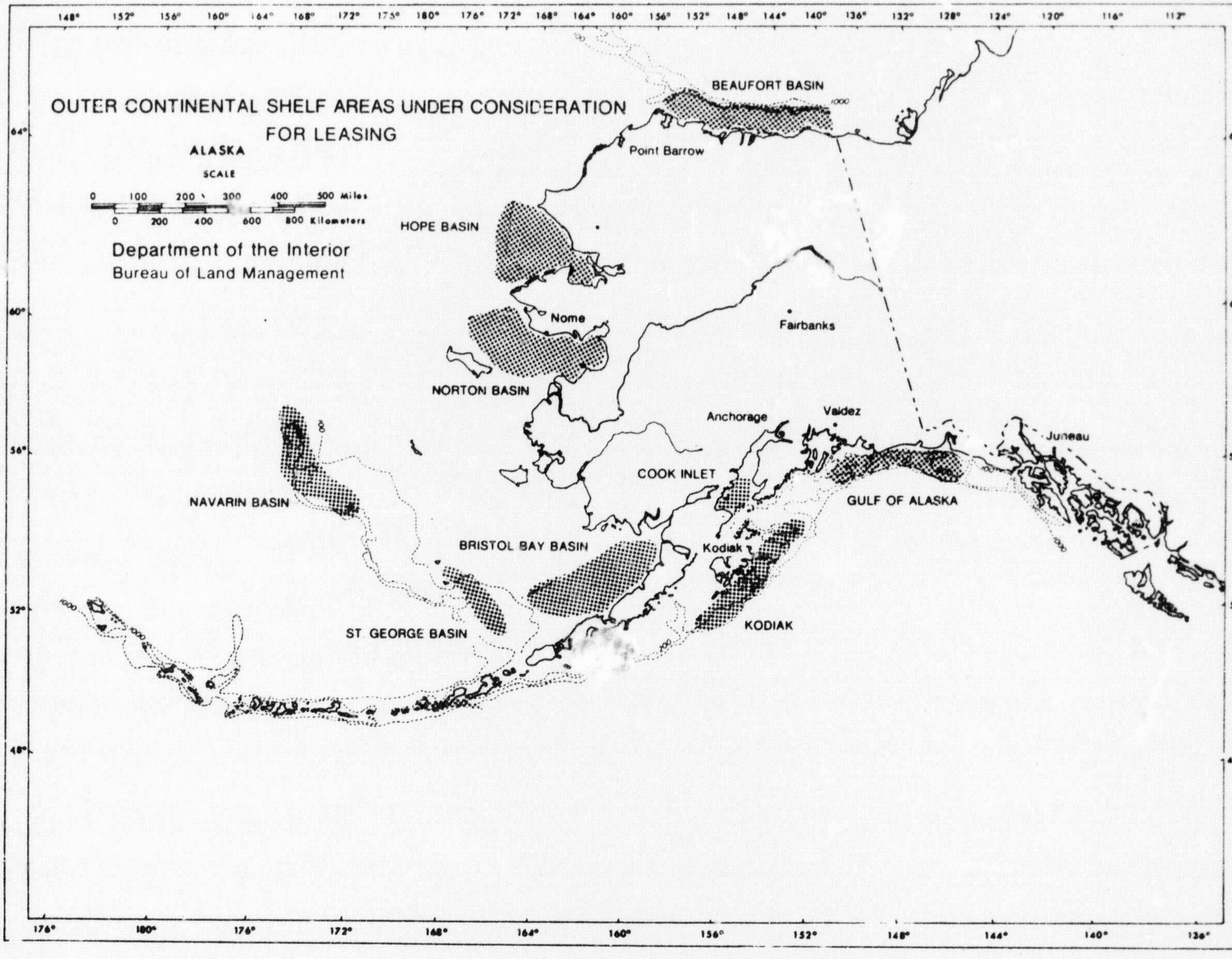

140°
135°
130°
125°
120°
45°
50°
40°
45°
35°
40°
30°
35°
25°
30°
130°
125°
120°
115°
110°
Seattle
Portland
San Francisco
Los Angeles
San Diego
0 50 100 200 300 400 Miles
0 100 200 300 400 500 600 Kilometers

OUTER CONTINENTAL SHELF AREAS UNDER CONSIDERATION FOR LEASING

WEST COAST REGION

SCALE

Department of the Interior
Bureau of Land Management


OUTER CONTINENTAL SHELF AREAS UNDER CONSIDERATION FOR LEASING
ALASKA
SCALE
0 100 200 300 400 500 Miles
0 200 400 600 800 Kilometers
Department of the Interior
Bureau of Land Management
BEAUFORT BASIN
Point Barrow
HOPE BASIN
Nome
NORTON BASIN
Fairbanks
Anchorage
Valdez
Juneau
COOK INLET
GULF OF ALASKA
NAVARIN BASIN
BRISTOL BAY BASIN
Kodiak
KODIAK
ST. GEORGE BASIN
1000
200
148° 152° 156° 160° 164° 168° 172° 175° 180° 176° 172° 168° 164° 160° 156° 152° 148° 144° 140° 136° 132° 128° 124° 120° 116° 112°
176° 180° 176° 172° 168° 164° 160° 156° 152° 148° 144° 140° 136°
64° 60° 56° 52° 48°

As a result of the proposed acceleration of OCS oil and gas leasing, the Nation's prospects for finding and developing domestic supplies of hydrocarbon resources will be enhanced. At the same time, if accelerated leasing of the OCS is implemented, additional environmental and socio-economic impacts will occur, primarily in the Nation's coastal regions, as a result of increased exploration, development, and transportation of these hydrocarbon resources. It is the purpose of this environmental impact statement to analyze these potential impacts to determine the feasibility of an expanded leasing program as a whole, in terms of environmental and socio-economic costs and benefits.

On January 23, 1974, President Nixon addressed the Nation on proposals intended to deal with the energy crisis. He outlined an extensive legislative and regulatory program which he urged Congress and Executive agencies to act upon in 1974. Included were measures to deal with the short-term emergency of that period, as well as measures designed to achieve long-term self-sufficiency for the United States in energy supply (see Project Independence Blueprint prepared by Federal Energy Administration, November, 1974). Among these legislative proposals were:

- establishment of a Federal Energy Administration (implemented)
- mandatory reporting of information by private industry (in planning)
- market pricing of new natural gas (under review)
- Federal licensing of offshore deepwater port facilities (under review)
- elimination of depletion allowance for domestic oil and gas production (implemented)
- modernization of Mineral Leasing Act (under review)
- facilitation of the site selection, approval, and licensing process for energy facilities (in planning)

In addition to the legislative program, the President announced a number of executive actions designed to aid in achieving energy self-sufficiency for the United States. One of these, which is the subject of this final environmental impact statement, relates directly to outer continental shelf (OCS) oil and gas exploration and development:

> "I am directing the Secretary of the Interior to increase the acreage leased on the OCS to 10 million acres beginning in 1975, more than tripling what had originally been planned. In later years, the amount of acreage to be leased will be based on market needs and on industry's performance record in exploring and developing leases. In contracting for leases, the Secretary of the Interior is also to ensure that the proper competitive bidding procedures are followed and that environmental safeguards are observed. He will,

> in addition, set up an interagency program for monitoring the environmental aspects of the new leasing program. There will be no decision on leasing on the OCS in the Atlantic and in the Gulf of Alaska until the Council on Environmental Quality completes its current environmental study of those areas."

Pursuant to this directive, the Department of the Interior announced in the May 20, 1974 Federal Register that an environmental impact statement would be prepared concerning the proposed action of leasing ten million acres of OCS lands in 1975. This announcement was made because the proposal is considered a major Federal action significantly affecting the quality of the human environment, and therefore requires an environmental impact statement under the requirements of the National Environmental Policy Act of 1969. The Federal Register notice announced in part, that:

> "It is the intention of the Bureau of Land Management to prepare an environmental statement which, in general, will describe the following topics: The proposed leasing action; the management system pertaining to the proposed action, including leasing procedures, supervision, inspection, and regulation of lease operations and monitoring of actual and threatened environmental effects of lease operations; OCS oil and gas resource potential; energy supply and demand; technology for developing oil and gas offshore; environmental settings; natural phenomena that exist or occur in particular OCS regions, and which have the potential to cause of contribute to environmental impacts arising from the proposed action; the potential environmental impacts of the proposed action, offshore and onshore, including without limitation matters such as the cumulative impact of oil and gas operations under the proposed leasing action, impacts on competing uses of OCS resources, the effect of the proposed action

> on the level of environmental study prior to leasing and on the level of supervision of lease operations after leasing, and the degree to which environmental effects might be reduced as a result of improvements in methods of lease supervision; and the alternatives to the proposed action and their potential environmental impacts."

Non-dependence, or significant curtailment of dependence on foreign energy imports is one of the primary goals of Project Independence, which also contains proposals to research and develop alternate energy sources, to establish a climate of reduced energy demands through conservation practices, and to reduce energy losses through more efficient generation and transmission of energy. According to Project Independence Blueprint (PIB, p. 83), accelerated OCS leasing might produce as much as two million barrels of oil more per day in 1985 than our current production. This would amount to approximately 4% of United States energy demand. Beyond 1985, and including natural gas production, the USGS estimates that an additional three million barrels of oil and 12 billion cubic feet of gas could be produced beyond our current production. Were this oil being produced today, it would reduce dependence on foreign imports from approximately six to three million barrels per day.

As President Nixon's message indicated, this proposed increase in offshore leasing will not be undertaken until the Secretary of the Interior ensures that proper competitive bidding procedures are followed to assure a fair market return to the Federal Government on the production from the leases, and that proper environmental safeguards are observed.

The remainder of this final environmental impact examines the aspects of the proposed action announced in the Federal Register Notice referred to above. Discussions immediately follow on the scope of the proposed action and the underlying assumptions concerning both the proposed action and this final environmental impact statement.

2. Scope of the Proposed Action

The Presidential directive to rapidly accelerate leasing OCS lands in 1975 would have required leasing more than triple the acreage currently being offered annually for leasing. Certain events and new information indicate that this leasing goal is unattainable. First, a lease sale held in January, 1975, in the South Texas area resulted in only 626,000 acres being sold, where over three million acres were offered. Apparently, prospects of hydrocarbon finds in that area were not good (although no exploratory wells have been drilled); only $275,000,000 was taken by the Treasury from high bonus bids. Industry interest in an upcoming lease sale in the central Gulf of Mexico (over 3 million acres offered) might not result in much acreage being leased, in part due to declining prospects in that extensively developed area. A potential interim agreement between the Federal Government and the State of Alaska that would have allowed certain pre-leasing steps to be taken while the Supreme Court decided on ownership of Lower Cook Inlet oil and gas has been withdrawn pending the Court's decision. The proposed Mid-Atlantic sale can not be held in 1975 due to the delay in issuing a call for nominations until after the Supreme Court had rendered its decision on ownership of Atlantic OCS lands. The proposed sale in Southern California offers only 1.5 million acres, of which possible 50% might be leased (750,000 acres). It is entirely possible that no more than 3 million acres will be leased in 1975, even assuming that all six proposed sales are held. The November, 1974 schedule is being revised in light of these circumstances.

The scope of this proposed acceleration of OCS leasing through a program of specific lease sales in "frontier" areas is a salient point. Currently, the Nation's supply of domestic OCS oil and gas comes almost entirely from the Gulf of Mexico, specifically the Texas-Louisiana OCS. If a commitment is made to this proposed expansion of leasing, it would open new areas to leasing and development that have no history of OCS leasing of OCS leasing. Several indicators (BLM-GS estimates of tract worth, industry bidding patterns, OCS production summaries) show the central Gulf area to be one of declining potential for economically recoverable oil and gas reserves. As previously mentioned, prospects in the South Texas OCS are apparently not promising. Additionally, some of the most highly prospective areas in the eastern Gulf of Mexico (MAFLA area) are coming up dry from exploratory drilling results. If the indications of declining prospects in the Gulf are accepted as valid, then a significant increase in hydrocarbon supply can not be obtained by further leasing in the Gulf of Mexico alone. Therefore, any strategy of accelerated OCS leasing for the purposes of increasing production must include some geographic areas of the United States that have experienced little or no history of offshore oil and gas operations, the so-called frontier areas. These frontier areas include the Atlantic coast, lower 48 Pacific coast, and the coast of Alaska. The Atlantic and Alaska OCS areas have no history of drilling activity; Alaska has State coastal water development in Cook Inlet, but the Atlantic waters belonging to the coastal states do not currently produce any oil or gas. There has been some development of the coastal and OCS waters of Southern California; however, leasing of Federal lands in the Santa Barbara Channel has been suspended since the Santa Barbara blowout and oil spill in early 1969, and only limited drilling has occurred on existing leases.

The opening of frontier areas to OCS oil and gas leasing is a proposal that, if implemented, will result in significant changes in physical, social, and economic environments, as well as an expansion of management, supervisory, and monitoring systems within Federal and States' governments. Certain elements of the current OCS leasing program will carry over and be applied to an expanded program. Development in any frontier area will not begin until Operating Orders, similar in format to those used in the Gulf of Mexico, are developed for the specific geographic area. Current financial management procedures (e.g., type of bidding system) and commitment to intense compliance inspection will remain as general policy; however, the development of Operating Orders and other regulatory mechanisms will occur with the widely divergent physical, biological, and social conditions in the different OCS areas uppermost in mind. Under the July, 1973 schedule (that is, prior to the proposed acceleration), frontier areas were scheduled to be opened in Southern California and Alaska. In response to this plan, the Bureau of Land Management, in August and September, 1973, opened field offices in these two areas with responsibilities for collecting physical and socio-economic information, conducting environmental analysis on proposed development in the respective areas, and performing all the functions attendant to leasing lands in those areas. An Atlantic OCS Office was also established in December of 1973 with the purpose of environmental assessment of the area, but without a leasing function, as leasing on the Atlantic coast was contingent on the Council of Environmental Quality's assessment of the impact of oil and gas development in the area (released April, 1974), and the Supreme Court ruling in favor of the Federal Government concerning ownership of OCS lands.

The current lease sale schedule is a proposed four-year schedule of provisional leasing that was published in June, 1975. In the development of the schedule, the Department considered its three leasing objectives; orderly resource development, protection of the environment, and receipt of fair market value.

The present proposed schedule is ordered basically according to the principal of considering for leasing as early as possible those areas with the richest and most accessible potential reserves.

Subsequent to President Nixon's directive to expand OCS leasing in 1975, the Bureau of Land Management issued a request for comments on potential future OCS oil and gas leasing (Federal Register, February 20, 1974). These comments were to provide information concerning areas of interest for offshore oil and gas leasing and toward identifying problem areas. Seventeen areas were designated which encompass the OCS of the coterminous United States and Alaska. It was requested that these areas be ranked for oil and gas potential, and for environmental concern. The report on the responses received has been completed and is included as Attachment A.

This request for information is the first tier of the Department's two-tier nomination system, whereby the most promising offshore areas are identified through earlier release of industry rankings and interest, and the public interest in different geographic areas is also made known earlier in the leasing process. The second tier of the system involves analysis of rankings and public comments, and the nomination and selection of tracts within specified geographic areas for possible leasing and Department's own evaluation of resource potential and the impacts of development on the environment. This is followed by the currently employed phases of the leasing system: a site-specific draft environmental impact statement, public hearings in the affected area, Federal and State agencies and public review of the impact statement, and the development of a final environmental impact statement in which all the various inputs are summarized and from which conditions and stipulations of the lease sale are formulated. The leasing process is more fully discussed in a later section.

Since this is an impact statement on the initiation of a large scale program, by its very nature, much of the environmental information presented is broad in scope. In particular, the descriptions of the OCS and the coastal zone for the U.S., could easily entail numerous volumes of information but the information has been condensed in this impact statement. The detailed aspects of leasing in a given geographic region are more appropriately handled in a site-specific impact statement. Such site-specific impact statements will be prepared in the normal course of the pre-leasing procedure, i.e., call for nominations, tract selection, preparation of draft site-specific impact statement, public hearing and comment period, preparation of final impact statement, preparation of a decision document setting hydrocarbon resource values against environmental risks, and decision on proposal.

One other reason for the generalized approach derives from the fact that many OCS areas are of a frontier nature regarding OCS hydrocarbon development. While these areas can be described in physical, biotic and socio-economic terms, the impacts and stresses of development will be wholly new. Much of the information used for projecting impacts is derived from Gulf of Mexico experience which, while it offers many insights and some conclusions regarding impacts, does not always correlate with the unique and varied characteristics of other regions.

Many of the impacts can be generalized for all the OCS regions. For example, impacts on phytoplankton or benthos are more important for their aggregate or cumulative effects than for the individual impacts on certain species. The attempt is made herein to identify and highlight those resources that are of particular value or vulnerability in any given region. Also, the natural hazards to development are considered an important parameter for analyzing the possible range and intensity of impacts in different regions, Proximity of development to nearshore and coastal resources is also considered an important factor in analysis of impacts, as are the anticipated intensity of development (based on the estimated hydrocarbon potential) and mode of transportation of product. These various factors constitute those parameters that are analyzed and portrayed in matrix fashion in Section III on impacts. The analysis then leads to determinations of the relative environmental risks of development in all OCS regions. Subsequent chapters then discuss methods of mitigation and alternatives to the proposal that may alter the cost-benefit considerations of an accelerated OCS oil and gas leasing program.

B. Proposed Oil and Gas Resource Management and Supervisory System

Proposed OCS Leasing Procedures (Administered by BLM)

a. Proposed Lease Sale Scheduling

The proposed schedule of lease sales through 1978 is presented in the previous section. As explained earlier, this schedule is based primarily on a strategy that opens areas of high resource potential and high accessibility early in the sequence of lease sales. All OCS areas are treated as potential lease sales areas in this EIS.

b. Proposed Permittee-Lessee Geophysical and Geological Data Submission and Disclosure Requirement

The Department is considering amending the regulations issued pursuant to the Outer Continental Shelf Lands Act (OCS Act) with the objective of imposing new requirements with respect to geological and geophysical exploration under permits and pursuant to leases on the Outer Continental Shelf and the disclosure of information and data obtained by such exploration. A public hearing was held on July 15, 1974 at the Department of the Interior Auditorium on geophysical and geological data submission and disclosure.

The USGS released a draft EIS on the proposed changes in the regulations governing release of geological and geophysical information on April 16, 1975. (See Attachment I)

c. Two-Tier System for OCS Leasing Areas and Tract Selection

(1) First Tier

(a) Request for Views of Interested Parties Concerning Areas of Resource Potential and Environmental Concern

On February 20, 1974, in the *Federal Register*, there appeared a request for comments from all concerned groups on potential Outer Continental Shelf (OCS) oil and gas leasing. The Bureau of Land Management and Geological Survey reviewed all the responses received and have produced several rankings of the 17 OCS areas. The Bureau received 63 responses, 25 of which were from oil or related industries. The remainder of the responses were from environmental groups, State and local governments, and from private citizens.

In general, the oil companies responded with a ranking of the areas according to resource potential although a few companies also ranked the 17 OCS areas according to their individual preferences. Some of the companies, but not all, presented mapped data. Those which did so outlined areas of interest rather than individual geologic structures. Also some companies, but not all, gave estimates as to time periods required to achieve *initial and peak* production and identified factors that may be constraints to development in the OCS areas.

Ranking according to environmental concern was requested in the Federal Register Notice; this particular request was not specifically directed toward the petroleum companies. Nevertheless, a few companies did submit a ranking according to relative degree of environmental hazard.

Specifically requested from environmental groups was a ranking of the areas according to environmental concern. None of the responses from environmental groups, however, presented this ranking. The consensus was that not enough information on the consequence of offshore development is available to make such a ranking. Likewise, the environmental groups which responded indicated that there is not sufficient information to indicate on maps specific environmental features or hazards. Instead, most of the responses called for increased study and analysis of the OCS environment before any decisions on leasing are made.

(b) Evaluation of Interior and other Federal Agency Reports on Resource Potential and Environmental Concerns

Responses were received from the following Bureaus within the Department of the Interior regarding offshore areas: 1) United States Geological Survey, 2) the Bureau of Mines, 3) the Bureau of Outdoor Recreation, 4) the National Park Service, and 5) the Fish and Wildlife Service. Responses were received from the following

Federal agencies: 1) National Oceanic and Atmospheric Administration, 2) Department of Defense, 3) Federal Energy Administration, and 4) Federal Power Commission. In addition, the Council on Environmental Quality's report on environmental considerations in the Atlantic OCS and the Gulf of Alaska, ordered by the President in April 1973, was released in April 1974. The CEQ report is discussed in detail in later sections of this EIS. Also discussed in later sections is the Project Independence Blueprint (PIB) prepared by the Federal Energy Administration.

In addition to the Request for Comments that appeared in the Federal Register, the Bureau of Land Management requested resource reports from the aforementioned Bureaus within the Department of the Interior. In the request for resource reports, these Bureaus were asked to submit comments and data on their respective areas of concern.

The USGS estimated (March, 1974) that undiscovered recoverable resources on the OCS to 200 meters water depth totaled 58 to 116 billion barrels of oil and 355 to 710 trillion cubic feet of gas. Total onshore and offshore undiscovered recoverable resources were estimated to be 200-400 billion barrels of oil, and 1000-2000 trillion cubic feet of gas. More recent estimates (DOI Press Release, May 7, 1975) by USGS indicate total U.S. undiscovered recoverable crude oil to be 50 to 127 billion barrels, and total U.S. gas to be 322 to 655 trillion cubic feet. A full report from USGS is expected very soon on these estimates. Estimates for 17 OCS areas were provided by USGS for oil spill analysis in Section III of this EIS.

The Bureau of Mines prepared an analysis of the supply and demand of petroleum until 1980. It is predicted that the demand for oil in 1980 will be 20.8 million barrels per day and for gas 34.5 trillion cubic feet per year. However, supply is estimated at 11.7 million barrels per day and 20.4 trillion cubic feet per year. These projections were made, of course, before Project Independence and the recent directive by the President to accelerate the OCS leasing program. In the present day tight domestic supply situation, markets for petroleum are characterized by greater demand than supply. Depending on location of resources, certain patterns of processing and consumption likely would develop. That is, oil production from the Atlantic OCS would most likely be processed in refineries along the Atlantic seaboard and consumed in nearby eastern States. Likewise, gas from the Atlantic OCS would also be consumed in these areas. Similarly, production in the Pacific OCS would probably be processed and consumed in the Pacific seaboard and adjacent States. Increased oil production in the Gulf of Mexico is expected to be refined in Gulf coast refineries as is currently being done. Because of past activity in the prolific Gulf of Mexico hydrocarbon areas, an extensive network of pipelines carries hydrocarbons to many areas of the country. Gulf of Mexico hydrocarbons serve 36 of the 48 coterminous States. Presumably some of the increase in production that would result from accelerated activity in the Gulf of Mexico within a few years will serve to satisfy the increased demand for petroleum in Gulf Coast States, but the remainder will likely be piped to the other States that depend on Gulf of Mexico oil and gas. Alaskan production probably will be processed on the Pacific seaboard for consumption in Pacific and western States.

The National Park Service, the Bureau of Outdoor Recreation, and the Bureau of Sport Fisheries and Wildlife have categorized according to location some of those historic sites, national park areas, refuges, fishing areas, etc., that would be impacted by hydrocarbon activity. These reports have noted that the possible oil and gas lease sales in OCS areas represent many potential threats to the recreation environment. These reports assume a constant threat of damage from oil leakage or spills. The report also observes that construction of pipeline terminal stations and related roads and facilities could eliminate some future opportunities for water-oriented outdoor recreation. They note that platforms and rigs visible from shore can have negative visual impacts and that their construction and operation may result in oppressive noise or objectionable odors.

Besides the resource reports requested from other Bureaus within the Department, the Bureau of Land Management contacted other Federal agencies for their responses to the questions asked in the Federal Register notice. The agencies contacted were: 1) the Department of Commerce, 2) the Department of Defense, 3) the

Department of Transportation, 4) the Department of Treasury, 5) the Environmental Protection Agency, 6) Federal Power Commission, and 7) the Federal Energy Administration. The following is a summary of responses of other agencies received by the Bureau of Land Management.

The National Oceanic and Atmospheric Administration (NOAA, Department of Commerce) has provided data gathered in relation to fisheries in the Gulf of Mexico, the South Atlantic and the Pacific. In these reports, they call for the following specific actions to preserve fishing resources from potential damage from hydrocarbon development activities. All of these actions have been implemented or are being considered by the Department.

1. Wells and platforms should not be located in coral reef areas.
2. Platforms should not be located on steep slopes, as these are prime fishing areas for species such as snapper and groupers.
3. Drill cuttings and muds should be discharged so as to settle outside areas of productive benthic assemblages.
4. Submerged wellheads should be capped below the surface of the ocean floor or well marked with buoys.
5. Wells should be spaced far enough apart to permit trawling operations in the area.
6. All construction debris should be removed and disposal should be onshore.

7. Pipelines to onshore facilities should be consolidated into pipeline corridors.

8. Pipeline corridors should be located so that they do not traverse estuaries or that they traverse the least sensitive estuarine area. Productive bays and marshes should not be disturbed.

9. Pipelines should be buried beneath the ocean floor. Where they cannot be buried, they should be well marked with buoys and all buoys must be maintained.

10. In areas where obstructions already exist on the bottom, wells should be located near the obstructions to reduce further loss of fishing grounds available to the trawl fishery.

11. Onshore facilities must be located outside productive estuarine systems.

In addition, NOAA recommended that in order to preserve unspoiled water environments, there should be no haphazard array of development sites. Rather, the sites of hydrocarbon activity should be arranged, to the extent possible, in small clusters separated by no less than 50 miles. NOAA observed that density greater than this will increase the severity of effect upon fisheries and other marine estuaries resources.

The Department of Defense stated a preference for reviewing each leasing proposal on a case-by-case basis as they have done previously. Therefore, DOD did not wish to issue a commentary that would be inclusive of the entire OCS.

The U.S. Coast Guard (Department of Transportation) made the following comments in regard to OCS leasing. The Bureau of Land Management should avoid leasing in navigation routes but if necessary, consideration might be given to relocating such things as traffic separation schemes and ocean dumping areas where feasible and reasonable. The response from DOT mentioned that there are fishing areas listed in the Code of Federal Regulations, but if appears that there is no regulation to isolate the fishing areas from the leasing of oil and gas properties.

The Federal Power Commission discussed what they consider may well be the primary policy question to be decided with respect to future OCS leasing programs. This question is whether to focus attention on the frontier area of greatest potential i.e., Alaska, or to lease acreage in each of the major offshore areas with the goal of obtaining a more diffuse supply. To develop the Alaska OCS may be the most economically efficient method but, if the areas for development are more diverse, the Nation will have a more assured supply of petroleum. In regard to environmental protection, the FPC called for greater cooperation among agencies and advanced planning to reduce potential conflict between environmental protection and oil and gas activity.

(2) Second Tier

(a) Public Notices Identifying Permittee-Lessee Geological and Geophysical Data Reports for Potential Leasing Areas

It is proposed that a public notice be published prior to the selection of tracts which would call for all geological and geophysical data that is to be disclosed as discussed above.

(b) Call for Nominations for More Specific Areas

The general areas for leasing on the Outer Continental Shelf (OCS) are selected by the Bureau of Land Management (BLM) and U.S. Geological Survey (USGS). After the general areas are selected a call for resource reports from the various government agencies that have interests in OCS activities follows. The resource reports identify particular areas on the OCS that should not be offered for leasing because of the potential danger to the environment and/or resources such as marine life, defense considerations, recreation, etc. At the same time that resource reports are requested, a call for nominations is published in the Federal Register; this is a formal request to industry and the public requesting which tracts they would like to see the Government offer for leasing. These tracts are in the general area that was selected previously. After the particular tracts are nominated, BLM-Washington Office (WO) and GS-WO review the nominations.

(c) Request for Views of Interested Parties Concerning Resource Potential and Environmental Concerns for More Specific Areas

Industry, Federal and State Government agencies, and the public are requested to respond on the resource potential and environmental concerns. It is hoped that these comments will assist the Department in evaluating the proposed area to be leased, and also to focus on potential problems that might be encountered if the area is leased.

(d) Tract Selection

The Washington offices of BLM and USGS select the general area for a sale proposal; this selection is long-range in that a cooperative effort enters the lease sale schedule preparation. The respective BLM and USGS field offices select the tracts to be offered in the area where a sale is proposed. Tract selection is performed after the nominations of tracts by industry and the public have been received. BLM field responsibilities include identifying tracts on the following criteria: total number of weighted and non-weighted nominations per tract; nomination patterns; tract history; a mix of tracts by water depth, distance from shore, and nominations; and a thorough analysis of all available environmental information, including summary resource reports from other agencies. The USGS field office identifies tracts by the following criteria: potential development of geologic structures and trends; potential of drainage; background data submitted by industry on specific tracts; high prospects for production; and tracts amenable to prompt drilling and development.

After BLM and USGS prepare separate lists of potential tracts, the lists are compared, a joint review of all tracts identified as candidates for sale is held, and a joint recommendation is made to Washington of one integrated list of tracts. The Washington staffs of BLM and USGS review the field nominations, and produce the final list of tracts that undergoes analysis in the environmental impact statement process.

Prior to tract selection, USGS must insure that operating orders have been developed for the geographic region under consideration, and that the orders combined with adequate inspection programs have been instituted to assure compliance with the delineated equipment and procedures that mitigate environmental damages.

C. Description of OCS Oil and Gas Operations

All of the material in this section was paraphrased or excerpted from the following: Kash, et al. (1973); Greer (1973); Savit (1974); Brewer and Shrum (1973, and testimony of L. G. Otteman and G. C. Lee at Environmental Hearing, Louisiana Offshore Lease Sale (OCS Sale #36), New Orleans, Louisiana, June 5, 1974.

1. Oil and Gas Operations

a. Geophysical Exploration

The principal tool of the geophysicist is the reflection seismograph which transmits waves of energy into the earth's crust. They bounce off layers of buried rock, travel back to the surface and they are picked up by sensitive receivers and recorded on magnetic tape. These tapes are processed by computers and the final results are cross-sections as well as contour and isopach (interval thickness) maps which the geologists and geophysicists can use to locate areas and structures most likely to contain commercial oil and gas deposits.

(1) Energy Source

Before 1966 marine seismic surveys used dynamite as an energy source. Concern for personnel safety, potential damage to marine life and the high cost of dynamite prompted the development of alternate energy sources. Exxon's sleeve exploder - a method of detonating a gas mixture in an expanding rubber sleeve - was placed in operational use in 1968. Other energy sources (sparkers, air guns, gas guns, etc.) have been developed and today account for more than 95% of the marine seismic energy sources

(2) Data Collection

Energy pulses reflected from underlying formations are picked up by detectors towed behind the surveying vessel and recorded on magnetic tape for processing into usable information. Usually receivers are spaced along a single cable towed by the surveying vessel. These receivers can be tuned and/or filtered to emphasize the seismic signal and de-emphasize boat-generated and other water-borne noises.

By use of a detector attached to a buoy containing a radio transmitter, sonic velocities through the underlying formation can be determined, thereby aiding the geologists and geophysicists in their interpretations of the reflection seismic data.

(3) Navigation Systems

During marine seismic surveys it is important to be able to reference the seismic data with surface location. The most advanced navigation equipment is sought for use by the seismic survey vessel. This equipment includes both satelite and long range shore-based (Loran -C) systems which allow the ship's position to be known within a few hundred feet. Loran -C has an estimated accuracy of 50 feet 200 miles from shore.

(4) Data Processing

Originally, seismic records were multiple traces on long film strips which had to be "read" by the geophysicists and interpreted into the final map and cross-sections.

Modern, computerized methods read and digitize the data as received and record it on magnetic tapes. During processing, further extraneous signals (echos, ringing reverbrations, etc.) are electronically filtered and a true seismic portrayal is displayed for the interpreters.

b. Exploratory Drilling

The exploratory or "wildcat" well is the final step in the determination of whether or not an oil or gas accumulation exists at the location chosen by the geologist and geophysicists. Since the purpose of the exploratory well is to first verify the existence of oil or gas and secondly to determine the extent or size of the accumulation, a prime requisite of the drilling rig is that it be mobile.

(1) Shallow Water Drilling Equipment

The most commonly used wildcat drilling rig for water depths up to 300 feet is the "jack-up" rig. This rig, with the legs raised, is towed from location to location. Once on a new location, the legs are jacked downward to contact the seafloor and the hull with its drilling equipment is raised approximately 50 feet above the surface of the sea.

(2) Deep Water Drilling Equipment

Beyond the 300 feet water depth, the semi-submersible rig and the drill ship are the two types of equipment used to drill exploratory wells.

The semi-submersible can displace as much as 20,000 tons and some are even self propelled. Once on location they are anchored in place and partially submerged. This submergence adds to the overall stability of the unit and greatly reduces the amount of "heave" (the up and down motion). Because of these better stability characteristics, the semi-submersible is usually preferred over the drill ship.

The drill ship, as the name implies, is a ship with a drilling derrick mounted midship and hole through the hull through which the drilling tools are lowered. The drill ship is self powered and has better seagoing characteristics than the semi-submersible.

The choice between a drillship and a semi-submersible depends upon many factors such as: expected weather conditions, depth of hole, expected frequency of moves, distance between moves etc.

Both the drill ship and the semi-submersible can be held in place directly over the location by dynamic positioning. This system can be used whether or not the drilling vessel is moored. Dynamic positioning or automatic station keeping is achieved by use of a sonar transmitter located either onboard or on the seafloor (if located onboard, then designed reflectors are placed on the seafloor), hydrophones, an on board computer and as many as a dozen small thruster motors spaced around the periphery of the drilling vessel. The sonar signal (either direct or reflected) is received by three shipboard hydrophones and fed to an onboard computer which then displays the ships position relative to the wellbore and the ships position can be corrected either automatically or manually by manipulating the mooring lines and operation of the thruster engines. Shell has completed drilling operations in 2150 feet of water offshore from Gabon, Africa using the drillship SEDCO 445.

The developers now working on a tension-leg-platform (TLP) claim mobility as one of its assets and propose to use it for exploratory drilling. The TLP is described in detail in section C.1.c.

(3) Drilling Operations 1/

Once the wildcat rig is on location and either jacked up, moored or dynamically positioned and provisioned, drilling

---

1/ Operations described in this section are oriented to Gulf of Mexico OCS operations because that area has been under development for some years and is where much present technology has been developed and where new technology is being worked on.

operations commerce and these operations are basically the same regardless of the type of rig.

The first operation is to set the first string of pipe called "drive pipe", which is usually about 30 inches in diameter and is literally driven into the subsoil at least 100 feet and often deeper depending upon the structural integrity of the surface sediment.

Next is the installation of the blowout preventers stack (BOP). The blowout preventers, as the name indicates, is the first line of defense against a blowout or uncontrolled flow from a drilling well. Blowout preventers are of two basic types: 1) the bag type seals off anything in the hole by inflating a large rubber ring between the object and closing the hole. It is possible, but not recommended, to close the open hole with a bag-type preventer. The other blowout preventer is a ram-type. This preventer can be equipped with different types of rams viz: 1) blind rams close across the open hole, 2) pipe rams close around the drill pipe or tubing whichever is in the hole, and 3) shear rams which can cut through drill pipe if necessary. These blowout preventers are essentially large, powerful, fast acting, hydraulically operated valves. On a drilling platform the blowout preventer stack is located on top of the structural casing and just under the drilling floor; however for drilling from drillships and semi-submersibles, BOP stacks have been developed for installation on the seafloor between the drive pipe and the drilling riser. These BOP's are remotely operated, close in less than 10 seconds and can be used in any water depth. Next must be installed a drilling riser--a specialized string of pipe extending from the well head to the floating vessel. The riser must be flexible to allow for some movement of the drilling vessel; the riser is tensioned at the top to maintain its structural integrity. In deep and rough water the tension requirements may be reduced by equipping the riser with buoyant material. It is expected that bouyant risers can be designed for 3000-foot water depths within the current practical tensioner limits. The riser is essential to the drilling operation in that it provides for the return flow of the drilling mud and suspended cuttings.

The description of drilling operations is identical with that for Development Drilling in the next section C.1.c.

Exploratory drilling on the OCS by mobile rigs is regulated and inspected by the USGS and the Coast Guard. The scope of these regulations include personnel safety, equipment, rig power systems, pollution control procedures, casing setting procedures, mud program, and drilling safety equipment. Failure to comply in any of these items can result in suspension of rig activity until corrections are completed.

(4) Wildcat Well Completion and Abandonment

Should the initial test be dry, the well usually is plugged and abandoned. Cement plugs are set to confine formation fluids in their present subsurface formations to prevent them from intermingling and prevent flow to the surface. During plugging operations well control equipment (BOP's) remains in use; the casing is cut off at least 15 feet below the mud line; all obstructions are removed; and the bottom dragged to be sure no obstructions are overlooked. In some cases it may be necessary to drill several exploratory wells before condemning a prospective area.

If well tests show that commercial quantities of natural gas or oil have been found, it may be necessary to do several additional confirmation tests before the company is satisfied that the reserves will support a development drilling and well completion program.

It is also important to delineate as precisely as possible the extent of the petroleum reservoir because of the extreme expense of deeper water platforms and the economic necessity of drilling as many production wells as possible (sometimes over 30) from a single platform. Platform location in relation to hydrocarbon deposits must be extremely accurate to minimize the number of platforms installed.

If petroleum deposits prove to be commercial, one of two courses of action may be followed:

(a) The exploratory well may be deemed expendable and be permanently abandoned. Procedures followed would be the same as above for a dry-hole abandonment.

(b) The well may be deemed useful as a future production well and temporarily abandoned. In this case, a mechanical bridge plug is placed in the smallest string of casing and the well head capped and left for future entry when production activity commences. This results in the temporary existence of an underwater "stub". The Coast Guard District Commander requires that such stubs be marked by a buoy at the surface if located in 200 feet of water or less, and that the buoy be lighted if located in 85 feet of water or less.

(5) Onshore Activities Associated with Exploratory Drilling

Dockside and service support, including transportation of crews and supplies to drilling rigs is required. Many of the required onshore support services are not specific to the oil industry. These include trucking companies, welding shops, cement supply companies and machine shops. As the number of working rigs in an area increases, new specialized services would be attracted to any area without an existing service infrastructure, and existing non-specialized services might have to be supplemented. Examples of specalized services include drilling mud supplies and specialized tool and equipment supplies. These are generally small operations with small land and labor requirements.

c. Development Drilling, Production and Workover

(1) Platform Installation

Offshore drilling and production operations are usually conducted on fixed, bottom founded, platforms which extend above the water surface. If exploratory efforts are successful in proving a hydrocarbon reserve, production operations are initiated by installing platforms to serve as a base for drilling development wells and for subsequent production operations. A number of wells may be directionally drilled to develop a large area from a single platform. Some platforms in the Gulf of Mexico OCS contain as many as 30 wells.

Platforms require land bases for fabrication. However, platforms do not have to be constructed in the production region. The Washington Post of March 11, 1975, pictures a semi-submersible rig fabricated in Baltimore and underway to the Gulf of Mexico. Platform fabrication yards may be stimulated by accelerated OCS leasing in frontier areas. The size of such a facility would depend on its design capacity. One of the major platform fabrication yards in Louisiana began with 150 acres and now covers 500 acres. It is preferable that such a facility be located on an inland waterway close to adequate land transportation. Unobstructed access to the open water is required.

Appropriate design procedures are outlined in API Recommended Practice RP 2A and various API specifications. These guidelines have been prepared to cover engineering design and operation of offshore structures and related equipment. USGS OCS Order No. 8 defines regulatory approval procedures for platform design and installation.

Platforms have been installed in the Gulf of Mexico in water depths to 373 feet, and technology exists to extend platform operations to much greater depths. Platforms are now being fabricated for installation in the North Sea in water depths to 500 feet. A permit for installation in 850 feet of water at the Santa Ynez Unit in the Santa Barbara Channel has been issued and the platform is under construction. A design for a 1020 foot platform for the Gulf of Mexico is underway.

The major difference between current operations and deep water platform installations will be the offshore erection techniques. In typical Gulf of Mexico template type structures, the lower portion, or jacket, is barged to sea, launched, upended and secured to the sea floor with piling driven through the legs. The deck section is then lifted into place and secured by welding.

Because of the large size of a platform for 800-1200 feet of water, the lower portion could be fabricated onshore and barged to sea in two or more sections. At least two methods have been devised and determined to be practical using current construction equipment for fabricating and installing multi-section structures. The 850-foot water depth platform for the Santa Barbara Channel will have two sections joined at sea in a horizontal position; the structure then will be upended by controlled flooding, set on bottom and secured with piling. The deck section will be set in place in a conventional manner.

In a second method, being developed for the Gulf of Mexico, the lower jacket portion will be built in three sections. The base section will be launched and placed on bottom with derrick barges then secured with piling. The upper two sections of the jacket will then be set successively in place atop the base. All three sections will be joined by cementing a large tubular member inside each of the platform legs. Finally the deck section will be installed in a conventional manner.

Buoyant towers have potential applications in water depths greater than about 1000 feet. These towers would be pivoted at the base and stabilized in a vertical position by bouyant chambers. Unlike conventional platforms, buoyant towers should sway under the action of wave forces instead of resisting them. In waters much less than 1000 feet deep, however, the sway of these towers would be excessive. Towers that would support two drilling rigs, production equipment, and 40 to 60 wells appear feasible for water depths between 1000 and 2000 feet. This type drilling platform has never been used on the U.S. OCS.

Another concept--the "tension leg platform (TLP)"--is in the model testing stage. This platform will be tethered to the bottom by cables attached to anchors, deadweights or grouted pilings on the sea floor. Just below the water surface is a buoyant section designed to maintain constant tension in the legs and support the working platform and its load above the water surface. The net effect is supposed to be a "tower" that will provide a stable working surface without presenting a rigid, inflexible structure against the forces of the sea. A one-third scale model (triangular 120 feet on a side) is now (summer 1975) being tested in 150 feet of water near Catalina Island. If the concept proves feasible, this "tension leg platform" would be used in water depths deeper than 600 feet. Maximum depth for this type platform has not been determined but it is expected to be in excess of 3000 feet. Also, this type platform should be more economic than standard platforms because incremental cost for deeper water is only the cost of mooring cables (the "tension legs"). The TLP should also be somewhat mobile, sufficiently so, claims the developer, that it may be used in exploratory drilling.

In some areas of the Gulf of Mexico OCS, unstable bottom conditions exist (II.A.2.a.(5)). In these areas special design and installation techniques are used to assure a stable and safe structure. This consists primarily of using fewer but stronger upright members through the unstable zone, jetting the entire template structure through the unstable sediments and driving piling well into the underlying competent subsoil.

In the arctic regions special precautions must be exercised to overcome the crushing and abrasive effects of ice. Very generally, structures in this environment have fewer but larger and stronger vertical columns through the ice zone. The members that do pass through the ice zone have extra wall thickness of specially treated steel to resist both the crushing forces and the abrasive wear of moving ice.

In the Gulf of Alaska and Pacific areas, seismic activity is of major concern. Techniques used to design large office buildings have been expanded to apply to offshore structures.

(2) Development Drilling

The drilling rig, power plants, generators, living quarters, storage sheds and other components, constructed in modular form, are added to the platform, and production well drilling commences. Equipment anticipated for use on deep water platforms is similar to that being used safely in current shallow water operations, and will be installed and operated in accordance with safe practices accumulated for industry experience. These practices form the basis of USGS OCS Order No. 8, which gives the safe practices a regulatory mandate. This order specifies multiple, redundant controls and safety devices including safety shut-in valves, high-low pressure pilots, high-low level controls, high-temperature shutdowns, gas detectors, shielded ignitions, fire prevention and detection equipment, and pressure relief systems. Drain and sump systems are also designed to collect any spillage that might occur on the platform.

As with exploratory drilling, the casing and mud programs, formation penetration, expected geologic hazards, bottom hole locations, etc., for each development well must be approved by the Geological Survey before a drilling permit is issued.

To describe the drilling process certain simplifying assumptions must be made. These assumptions are that the well will be:

(a) a development well (not exploratory)

(b) drilled from a multi-well slot platform using a standard platform mounted rig

(c) a "normal" well, i.e., one in which no special drilling problems or mud problems are experienced which would cause an abnormal volume of cuttings or usage of mud

(d) drilled to a total depth of 15,000 feet.

The casing program for this well consists of five strings:

(a) the structural casing, (drive pipe) is usually 30 inches in diameter. It is set to a minimum depth of 100 feet to provide stability in unconsolidated sediments

(b) the 20-inch conductor pipe, set at 900 feet

(c) the 16-inch surface casing, set at 3,500 feet

(d) the 10 3/4-inch intermediate string, set at 10,000 feet

(e) the 7-inch production string, set at 15,000 feet.

In drilling, two distinct, important pressures must be considered. One is the pressure within the geologic formation penetrated and the other is the pressure required to fracture or allow the drilling fluid to enter the formation below the last casing string and above the drill bit. These pressures are naturally occurring phenomena A drilling plan calls for maintaining a sufficient hydrostatic gradient to prevent formation fluids from flowing into the wellbore. This is done by adjusting the density or weight of the drilling fluid or "mud" that is continuously circulated through the drill string to provide pressure control. In addition to pressure control, the drilling mud has several additional important functions:

(a) it must be viscous (thick) enough to carry drill cuttings to the surface,

(b) it must be able to keep drill cuttings and weight materials in suspension when circulation is stopped,

(c) it must be able to release drill cuttings from suspension at the surface,

(d) it must form an impermeable cake on the wall of the hole to prevent loss of drilling fluid to low pressure formations,

(e) it cools and lubricates the bit and drill string, and

(f) it should allow electric and radioactive logging instruments to "read" through to the formation without masking the results.

The following table (Table 1) indicates the amount and kind of commercial mud components required in the drilling of this "typical" well.

In spite of considerable research, it is still not always possible to predetermine the formation pressure and the fracture pressure that the wellbore will encounter. This is particularly true in the case of wildcat wells. During drilling there are several means of determining the trend in pressure. They include measurements such as formation temperature (as evidenced by the temperature of the returning mud), shale density and changes in the penetration rate of the drill bit.

Table 1. MUD COMPONENTS USED IN SEAWATER-LIGNOSULFONATE SYSTEMS TO 15000 FEET AND DRILL CUTTINGS REMOVED FROM 15000 FOOT WELL 1/

	INTERVAL-FEET				TOTAL
	0-900	900-3500	3500-10,000	10-15000	15000 Feet
Mud Components - Thousands of Pounds					
Barium Sulfate (Barite)	3	3	529	625	1160
Bentonite Clay	10	10	36	9	65
Attapulgite Clay	5	5	-	-	10
Caustic	0.5	0.5	20	23	44
Aromatic Detergent	-	1	2	-	3
Organic Polymers	-	1	3	-	4
Ferrochrome Lignosulfonate			26	69	95
Sodium Chromate				2	2
Total Mud Components	18.5	20.5	616	728	1383
Drill Cuttings					
Hole Diameter (inches)	24	18	13	9	-
Volume of Cuttings (Barrels)	504	843	1100	405	2852
Weight of Cuttings (Thousand Pounds)	408	680	890	328	2306

1/ It is emphasized that these are "typical" values for the Gulf of Mexico OCS. Quantities may vary as much as 50% from well to well within this area and by even more between major areas of the OCS.

If the hydrostatic gradient of the drilling fluid becomes less than formation pressure, a "kick" of gas or other fluid may enter the wellbore from the formation being drilled. The influx displaces some drilling fluid, thereby causing reduction in the hydrostatic head in the annular space between the drill pipe and the borehole.

If the volume of the influx is not excessive, and a surface indication (increased mud tank volume) is observed, the unwanted influx of fluid or gas can be circulated out of the well by careful observation of well conditions and adherence to preplanned emergency procedures. From the record of a kick, the bottom-hole pressure can be determined and with this pressure known, the mud weight can be adjusted to provide the correct hydrostatic head for the safe continuation of drilling.

An uncontrolled kick is called a "blowout". Blowouts seldom occur and usually can be controlled by implementation of preplanned emergency procedures and actuation of the blowout preventers which are mounted on every offshore well during drilling.

Blowouts can occur downhole when a low-pressure formation fractures, and fluids from a higher-pressure zone flow into the fractured formation. Such underground blowouts, like surface blowouts, require the careful use of preplanned emergency techniques to regain control. Blowout preventers and other well-control equipment must meet the requirements of OCS Order No. 2. This equipment is tested on a schedule set by prudent practice, but not less often than regulations specify.

To ensure that adequate provisions have been made for safety and well control, the casing program and drilling fluid, or mud, program must be approved by the Geological Survey before a drilling permit is issued. Along with adequate casing, it is important that enough cement be spotted between the casing and the wall of the hole to seal off and isolate all sensitive geological formations such as hydrocarbon zones and freshwater sands, and to separate zones of abnormal pressure from those with normal pressures.

Blowout preventers on drilling wells and the redundant combination of wellhead valves and subsurface safety valves have proven effective in maintaining control of wells when the normal controlling devices (drilling mud and production regulators and chokes) have failed. Once shut-in, the wells can be reentered through either the blowout preventers or wellhead valve with drill-pipe or tubing to perform remedial work and bring the well back under control. This can be done if the blowout preventer or wellhead is on the sea floor the same as if they were located on a platform. Should a well get completely out of control and crater around and outside the surface casing so that the well could not be reentered, then an offset relief would have to be drilled.

As drilling progresses, the drilling mud is continuously circulated down the drill pipe and up the annulus carrying the drill cuttings from the bottom of the hole to the surface. At the surface the mud stream is run across and through a series of shale shakers, desanders and desilters to remove all the suspended solids (drill cuttings). The drill cuttings are discharged directly into the sea unless, of course, they should contain oil, in which case they are washed to remove entrained oil before discharging. The wash solution is retained and eventually shipped ashore.

The first 3500 feet of the well is drilled and two strings of casing set (900 feet of 20-inch and 3500 feet of 16-inch) using essentially seawater plus natural clay additives as drilling mud. At this point, after the casing has been cemented, the mud is so contaminated with cement that it is (the mud) discarded by dumping it into the sea, after first removing most of the barite by centifuging. The amount discarded could be as much as 1500 barrels of mud, depending upon the amount of cement contamination.

At this point the system is converted to a ferrochrome lignosulfonate mud and used to drill the remainder of the hole and set the other two strings of casing. As shown in the preceeding table, the mud now requires more and more weighting material (barite) to maintain pressure control, bentonite clay for gel strength, caustic for pH control and ferrochrome lignosulfonate for viscosity control. During the drilling process some excess mud is acquired while trying to balance it (the mud) for the desired properties and some is lost overboard entrained with the drill cuttings.

After the well has been drilled to total depth and before the production casing string (the last) is run, several electric and radioactive measurements are made in the wellbore. These measurements are made by special instruments lowered into the well. A continuous graphic log is created as the instruments pass each succeeding formation.

The last (production) string of casing (7-inch in this instance) is run and cemented after the well has been logged. The next step is perforating or "shooting" the interval to be open for production. This interval is chosen by "reading" the electric logs and deciding the location and thickness of the producing formation. Both the logging and shooting operations are performed with mud in the hole.

As the number of working rigs in an area increases, oil companies establish onshore operation bases from which some services and supervision, as well as transportation, can be provided centrally. Onshore operations bases require up to 50 acres, preferably an inland water site with access to the open sea. Dock facilities are needed, as well as water depths up to 15 feet to handle supply boats, crew boats, and tugs. Bases have helicopter pads and include office and warehouse space.

(3) Well Completion

(a) Conventional Platform

When the well is drilled, cased and perforated, the completion operation starts. At this point, the well is under control by virtue of the weight of the column of drilling mud; the blowout preventors, of course, are still connected and available to close in the well in case of emergency. Next, the tubing is run on a packer which seals off the annulus between the tubing and casing above the perforations. After the tubing has been set on the packer and hung in the casing head and a mechanical bridge plug set in the top, and the annulus between the casing and tubing filled with drilling mud, all possible connections with subsurface formations (tubing, and all casing annulus) are checked and tested to be sure the well is completely shutin. When it is absolutely certain that the well is completely shutin, the blowout preventers are removed and the preassembled well head (the "Christmas tree") is installed and connected to the flow line and the well is completed.

(b) Subsea Completions

The basic component of a subsea system is an individual subsea well drilled with a mobile rig. The wellhead is located on the sea floor, and flowlines connect to a nearby platform. The wellhead valves are remotely operated from the platform and are designed to close automatically if required. Reliability and safety of these systems has been field tested on 114 subsea completions since 1962. Of these, 48 are in the Gulf of Mexico and 40 are off the California coast. Water depth ranges from "shallow" to 375 feet.

Subsea completions follow the same general step-by-step procedures as for conventional platform completions. Needless to say the entire process is considerably more sophisticated.

One type of subsea well uses "wet" trees which are exposed to the seawater. The "wet" tree equipment is relatively insensitive to water depth, and can be installed in deep water in the same manner as in shallow water. Although the wet tree is insensitive to water depth, its current (1975) practical use is restricted by the limitations of diver capability--now recorded as 850 feet. Divers are still required to assist with flowline connections to wet trees; however remote connectors are being developed and are expected to be proven practical in 5 to 10 years. A "wet" tree which had been in service for over seven years was retrieved in 1974 and found to be in excellent condition.

Another more recently developed system is the "dry" system. Wellhead equipment is essentially the same as in a "wet" system, except it is housed in a dry, one atmosphere chamber on the sea floor. Flowline connection and maintenance work can be performed by workmen inside the chamber, in a normal atmospheric, shirt-sleeve environment. The workmen are transported to and from the chamber in a tethered, atmospheric diving bell which mates to the chamber, allowing completely dry access for non-divers. One such completion was made in the Gulf in 1972 in 375 feet of water and has been on production since. The chamber was re-entered successfully in 1973 for routine inspection and maintenance, and found to be in excellent condition. The depth limitation of this system is currently (summer 1975) stated as 1200 feet. The depth at which this system can be used is restricted by the wall thickness of the housing and diving bell and the capacity of the hoisting equipment. The choice between platforms and subsea completions is primarily economic. There is no clear cut dividing line, but with today's and near-term (1-5 years) technology, it is probably in the 800-1500 foot water depth range depending upon local circumstances.

(4) Production Facilities

Platform located production facilities consist of gas-oil separators, oil-water separators, gas scrubbers, compressors, pumps, storage tanks, instruments and controls. That, of course, is an over-simplification for the myriad of pipes, tanks, pressure vessels, valves, motors, pumps, and compressors. As mentioned in section I.C.1.c.(2), OCS Order No. 8 specifies multiple redundant controls and safety devices including safety shut-in valves, high-low pressure pilots, high-low level controls, high temperature shutdowns, gas detectors, shielded ignitions, fire prevention and detection equipment and pressure relief systems. Drain and sump systems are also designed to collect any spillage that might occur on the platform.

The production platform contains all the equipment and performs the same function as field gathering station does at an onshore location. The fluid produced from the well is some mixture of gas, oil and water in varying proportions. Depending upon the flowing well head pressure, this mixture may be subject to as many as three stages of gas-oil separation. The stage separation process recovers the driest gas and the largest volume of liquid.

The gas may be further processed through scrubbers to remove any entrained oil, water or other impurities before it is compressed and sent ashore by pipeline. If there is insufficient gas to sell to a trunkline, it may be reinjected into the producing formation as a pressure maintenance measure, used for gas lift, used as engine fuel to drive pumps and compressors. Only on rare occasions is gas flared and then requires a permit from the OCS Area Supervisor of USGS.

The oil/water mixture that comes from the gas-oil separator goes first to a free water knock-out where the free water is separated by gravity from the oil. Should some water be emulsified with the oil, this mixture is sent through heater and/or chemical treaters to break the emulsion and separate the oil and water. The oil is pumped ashore by pipeline and the water is further filtered and treated and then disposed of overboard.

(5) Workover Operations

From time to time a producing well will require remedial maintenance (workover) for any one of a number of reasons. Many workover operations such as cleaning parafin, changing storm chokes and even replacing gas lift valves can be performed by pumping tools down the flowline and tubing. Major workovers require the use of a drilling rig to kill the well by circulating heavy mud, remove the well head, put on blowout preventers and perform whatever is required to improve or rehabilitate the well.

It is during major workovers when the remaining wells on the platform are still producing, that the risk of a major platform accident and/or fire is greatest. Because of these hazards, workover operations are carefully planned to keep wells from getting out of control as well as to prevent or minimize the release of oil to the environment. The Geological Survey is in the process of revising Gulf of Mexico OCS Order No. 8 to restrict simultaneous production and drilling from the same platform under certain conditions. The restrictions will apply to workover operations as well as to drilling and producing operations.

From the safety standpoint, completion and workover operations must be conducted carefully, and it is their critical nature that, in all likelihood, makes these operations safer than they otherwise might be. Operators of swabbing and wire-line units are well aware of the hazardous nature of their work and are extremely cautious. Despite the potential hazard, safety records during wire-line and swabbing unit work are excellent.

d. Transportation of Produced Oil and Gas

Oil produced on the OCS can be moved ashore either by a tank vessel (barge or ship) or pipeline; gas, of course, can only be sent ashore by pipeline. As of 1971 only 3-1/2 percent of all OCS crude oil production was barged ashore; the remainder all came ashore in pipelines.

(1) Barges and Tankers

Tank barges are flat-bottomed vessels that may be self-propelled, towed or pushed. If they are towed or pushed, a sea-going tug is used as the power source. Tugs used for this purpose vary in size from 65 to more than 150 feet in length, and are powered by 350 hp to 4500 hp diesel engines. Although non-self propelled tank barges come in all sizes, three are most popular;

- 1000 ton capacity (7200 bbl.), 175 feet long, 26 foot beam, 9 foot draft.
- 1500 ton capacity (10,800 bbl.), 190 feet long, 35 foot beam, 9 foot draft.
- 3000 ton capacity (21,600 bbl.), 290 feet long, 50 foot beam, 9 foot draft.

One tugboat of 4500 hp is easily capable of pushing ten of the 3000 ton barges that are lashed together. Some barges are provided with a notch in the stern into which the tug may be fitted and secured; others are towed by being lashed to the port and starboard sides of the tug.

Self-propelled barges that may be used offshore have capacities ranging from 20,000 to 25,000 bbl. A 20,000 bbl. barge averages 200 feet in length, 50 feet in width and draws 9 feet of water; 25,000 bbl. barges are all relatively new, are only slightly longer (236 ft.) than their predecessors, but are the same width and draft. Larger 30,000 bbl. barges are under construction. All self-propelled barges and tankers must be inspected and certified by the United States Coast Guard. Power is provided by two 1000-1500 hp diesel inboard engines, each connected to a powerful screw which moves the barge at an average open water speed of 10 knots.

There are three basic barge designs: 1) single skin (hull), 2) double skin, and 3) barges having independent cylindrical tanks. Single skin tank barges have both bow and stern compartments that are separated from the midship by collision bulkheads. The entire midship shell of the vessel constitutes the cargo tank with structureal framing inside. Double skin barges have an inner and an outer shell with the inner shell forming the cargo tank. This double skin structure provides added protection in case of collision, grounding, or some other mishap. Barges with independent cylindrical tanks are used for transporting liquids under pressure or where pressure is to be used to off-load the cargo; these will not be used for transportation of crude oil. In any case, barges usually do not have compartmentalized storage tanks.

The transfer of petroleum either into, or out of, a barge is a relatively simple operation. The vessel is docked either at an offshore platform or shore-based offloading facility usually with the aid of either an active rudder or a bow-thruster. Docking can be accomplished with relative ease in seas up to 5 feet. Once secured, hoses are connected to a manifold located on either side of the barge. These hoses must be equipped with a "quick-disconnect" apparatus in order to prevent a back flow from the hose from discharging into the sea. The coupler, because it may contain up to one-half gallon of oil, must have drip pans placed beneath it in order to catch any oil before it could spill into the water. The U.S. Coast Guard requires that a certified tankerman be present and on duty at the manifold during any oil transfer operations. After loading, or offloading, is completed, the transfer hose is drained dry by back flowing or draining the crude to the platform. The couple is then broken, and either a receptable is placed over the end to catch the drippings or the hose is plugged directly.

Loading of crude oil is usually done by means of a gravity feed system either from platform storage tanks or directly from the well. Offloading of crude to shoreside facilities is accomplished by pumps located on the barge or shoreside. The average rate of loading or discharge is approximately 4000 bbl./hr.

A tanker is a self-propelled ocean-going vessel that is compartmentalized into tanks for transport of liquids. Tankers are much larger than tank barges, the smallest used in crude oil transport is about 10,000 deadweight tons (dwt) or 65-70,000 barrels capacity. For use on the OCS, the size tanker that could be used would be limited by the allowable draft at its unloading port. Barges and/or tankers may be used initially in the new areas until sufficient producing capacity is developed to justify a pipeline.

(2) Pipelines

Pipelines laid offshore are constructed and laid by several different methods, depending mainly on the size, location, intended use, and cost. One method, pipepulling, involves the use of barges and tugs to pull sections of welded pipe from an onshore launchway over the preselected right-of-way. These sections may either be dragged along the bottom or suspended by floats. There are at least three limitations to this system. First, an extensive section of shoreline, roughly perpendicular to the shore, must be available for the fabrication and launchway site. (Alternatively, it is possible although more costly to use a launching jetty constructed from the beach out over the water.) Second, the total length of pipeline that can be laid is limited. One company estimates the limit to be 100,000 feet for smaller diameter pipe. Third, the pipeline right-of-way must be essentially a straight line. The pipe pulling method is not used often for laying pipelines to OCS locations.

Offshore pipelines, particularly large diameter or long lines, are usually installed using a barge specially constructed for marine pipelining called a "lay barge". This barge is a self-contained unit including all of the facilities required to join the pipe by welding, cover the weld with protective coating, and to lower the pipe into place on the ocean floor. The pipe is coated on shore and delivered to the lay barge in uniform lengths or "joints" with the ends prepared for welding. Several anchors, at least two at each corner, are used to hold the barge in position. Joints of pipe are welded together on the deck of the lay barge to form a continous length. When a weld is finished, inspected and coated, the barge is moved forward allowing the assembled pipeline to extend over the sterm of the barge and to sag downward to lay on the ocean floor. A new length of pipe is added to the "forward" end of the pipeline and the process is repeated.

Making a high-quality pipeline weld requires a reasonable amount of time. Therefore to obtain rapid production, "assembly line" techniques are used allowing welding to take place at several stations simultaneously. To do this the work on the barge must take place in an almost level position. From the barge to the ocean floor the pipe will assume a double curve or "S" shape. If the pipe is too heavy or too stiff to reach the bottom unsupported a buoyant pontoon or slide called a "Stinger" is used to provide support for the upper section of the pipeline. To help support the weight of the pipe and to prevent buckling, a carefully controlled tension force is applied to the pipe by constant tension machines mounted on the barge.

The pipe assembly process utilizes the latest technology and the best welding techniques currently available. All joints are given a complete X-ray inspection for quality and then covered with corrosion resistant material prior to leaving the barge. Offshore pipelines are designed and installed to meet the same codes and specifications as onshore pipelines, such as API, ANSI, ASME, etc. After the line is completed, it is tested to make sure that it has been properly installed and will withstand the anticipated operating pressures safely. The pipe is further protected by cathodic protection systems to supplement the corrosion resistant coating.

To handle the quantities required, offshore transmission lines have usually ranged between 24 and 36 inches in diameter. At the present time lines of this size extend to water depths of approximately 250 feet in the Gulf of Mexico. With existing equipment and utilizing current construction techniques, lines of this size can be layed to water depths of approximately 500 feet; however, both the pipe and the coating must be properly designed for strength and weight characteristics. A 32 inch diameter line will be layed on the North Sea in water depths up to 500 feet in the near future. Also in the same areas, a contract has been let for a 36-inch line in water depths of 540 feet for installation in the summer of 1975. Weather conditions in the North Sea are more severe than the Gulf of Mexico; therefore, if these pipelines can be installed and operated satisfactorily in the North Sea, they should be practical for the Gulf of Mexico also. Large diameter transmission lines can be installed to platforms or terminals appropriately located adjacent to deep water production. To reach to the deeper water beyond the platform, one or more smaller lines can be used in place of the transmission line.

It is believed that present-day techniques and existing equipment currently in the Gulf of Mexico can lay pipelines of 12 to 18 inches in diameter to 1200 feet with only minor modifications. At the present time no lines approach this depth; the deepest pipelines installed in the Gulf of Mexico are in approximately 400 feet of water. When such deep water lines are layed the same proven methods and technology that are now used will be employed. Studies and designs made for areas all over the world, verify that installation in these depths is technically feasible.

Practically all large and intermediate size offshore pipelines are covered with corrosion resistant coating and a concrete coating. The purpose of the concrete coating is to add weight to hold the pipe in place on the ocean floor, primarily to resist currents. The additional weight makes the pipelines more difficult to install. Fortunately, bottom currents are less severe in deeper waters, particularly the currents associated with wave and storm action. This allows reduced weight coating for deep water, which simplifies installation.

Flowlines between platforms and underwater wellheads could conceivably reach to water depths as much as 6000 feet (approximate depth of bottom of continental slope). These lines will range in size from 3 to 8 inches in diameter with a wall thickness relatively large compared to the diameter, which will provide good resistance to buckling and eliminate the need for weight coating. Both of these factors make the pipe more flexible and easier to handle. These flowlines can be installed with a lay barge using techniques similar to those previously described. However, for the deeper water ranges, it will probably be desirable to use an inclined "high angle" ramp that is adjusted so that the pipeline leaves the barge at the proper angle to reach bottom in a single curve or "sag" bend, similar to a cable held in a catenary. This eliminates the need for support from a stinger and reduces the stress on the pipe. The laying rate is reduced as fewer working stations are available. This procedure has been very thoroughly developed, but only limited applications have been made to date.

Holding the barge in position by anchors becomes more difficult as water depths increases, and moving anchors to allow the barge to progress along the pipeline route will be more time-consuming. If this becomes a problem, it may be desirable to provide auxillary propulsion to assist moving the barge ahead and to counteract the tension which is applied to the pipeline. It may also be desirable to consider a "dynamic positioning" system similar to that used on some floating drilling vessels. This is basically a computer controlled, all-direction propulsion system to hold the vessel in a fixed position reacting to the effect of wind, wave, and current.

At the present time, it is the opinion of the industry, that it has the capability of laying 24-26 inch diameter pipe in water depths up to 500 feet; 12-18 inch diameter pipe in water depths up to 1200 feet, and 8 inch diameter pipe in water depths up to 2100 feet.

In depths under 200 feet present OCS administrative procedures requires burial of the pipelines. The minimum depth of burial is 3 feet except in shipping fairways and anchorage areas, where the minimum depth is 10 feet. Burial is effected by jetting sediment away from underneath the pipeline and allowing it to sink into the resulting trench. The equipment used in this operation consists of a work barge equipped with high volume/high pressure water pumps and air compressors. From the barge, a multiple membered towline consisting of a strength member, water line, and air line extends downward to a U-shaped structure which straddles the pipelines and glides along it on rollers. Affixed to the U-shaped jetting device are several nozzles which direct water and air, under high pressure, ahead and below the pipeline. Sediments are blasted out of narrow trench by the water jets, partially lifted by the air and deflected to the sides by various types of fins. The suspended sediments fall diffusely along either side of the trench. As the jetting device is pulled forward, the pipeline settles into the trench and is partially buried quite soon by the reworked sediment as it slips and settles back into the depression. Complete burial and restoration of original bottom contours may require additional time. In shallow waters, experience has shown contour restoration to be quite rapid, whereas in deeper waters, more than a year may be required.

Even though a buried line is protected from fluid forces it is not necessarily stable. If it is too light, it will gradually work its way up through the soil and become exposed to the water forces. If it is too heavy, it will gradually sink in the soil and impose additional tensile stress in the line. Design procedures for determining the vertical stability of the line in sands and clays have been developed and are available in the industry.

Difficulties have been experienced in burying pipe in cohensionless sands. In this case the sand will often refill the jetted trench before the pipe can settle into it. Another method, fluidization of the sand, enables successful burial in this type of substrate.

To prevent corrosion, pipelines are carefully coated with such materials as epoxy compounds or thick asphaltic mastic. If extra weight or mechanical protection is needed, these, in turn, are covered with a layer of dense concrete. The lines are protected from electrolysis by both impressed-current systems and by sacrificial anodes (zinc is commonly used). These systems become active only when the coating has been damaged and bare pipe exposed; thus installed anodes are expected to last the life of the pipeline.

Corrosion prevention measures are now required by 49 CFR Part 195. Although offshore pipelines are relatively inaccessible as compared to onshore pipelines, they nonetheless can be repaired by divers. Experimental dives have been made to 1,000 feet, but work at this depth is difficult and expensive. Methods of using submersibles to latch on to a subsea line and repair it with mechanical arms and special tools are under study and nearing the point of practical demonstration.

As in the case of workover operations, the expense of the pipeline installations, coupled with the catastrophic implications for the local marine environment should a major break occur, have combined to dictate a highly conservative design, emplacement, and operating philosophy.

As the pipeline construction approaches and traverses the shoreline, it is buried deep enough to avoid its being exposed by storm-associated beach erosion. From this point the pipeline construction will be extended toward a storage facility, wharf facility, or a major existing pipeline system, in turn leading to a processing facility, refinery, or interstate gas line.

Onshore oil pipelines require pumping stations and some storage facilities. The pumping facility, a small building, is generally located close to the coast. In the Gulf of Mexico, a terminal facility including a pumping station, and storage tanks is common; however, it is not necessary to place storage tanks either in close proximity to the pumping station or near the coastline.

Onshore pipelines would carry oil to a refinery. Gas pipelines lead directly to gas processing facilities. Ultimately, the location of onshore pipelines is controlled by state and local jurisdiction.

Pipeline Operation and Maintenance

The safe operation and maintenance of a pipeline system requires several redundant monitoring systems to ensure the integrity of the line and detect leaks. The primary leak detection system in use (required on all lines built after March 31, 1970 by 49 CFR Part 195.406 and 195.408) is a set of automatic pressure sensing recorders on both ends of each pipeline system. These devices are equipped to either shut down the flow automatically or sound an alarm to alert personnel of an abnormal pressure level. In this way, a leak of substantial rate is detected immediately. This system is insensitive to leaks which do not produce a decrease in line pressure greater than 300-500 psi. It is essentially a safeguard to prevent the escape of large volumes of oil due to a catastrophic line break.

The second system of leak detection is the routine patrolling of the offshore wetlands routes by boat or aircraft, and onshore by wheeled vehicle or aircraft. A minimum patrolling frequency of intervals between inspections not exceeding 2 weeks is required by 49 CFR Part 195.412, but in actual practice is performed more often. This type of monitoring would result in the detection of all sizes of leaks of course, but would be of little consequence in preventing the loss of a large amount of petroleum in the event a large line were severed. The appeal of a system of regular pipeline patrolling is that it allows detection of small leaks and therefore complements the pressure-sensing system described above. With the present day volume of airborne and waterborne traffic over the oil producing area of the Gulf of Mexico, it is considered highly improbable that any spill would go undetected for any appreciable length of time.

The third system for leak detection consists of a series of volume-recording flow meters on either end of a pipeline system. Because nearly all crude oil moves from OCS areas to shore by common carrier lines, it must be metered in the offshore pipeline gathering system and again at the onshore pipeline terminal in order that each producer be properly credited for his share of the common stream. The flow sensors continually measure input and output in real time; thus when attendant personnel record these readings for inventory control they are able to discover a decrease in output which would indicate the possibility of a small leak. This is usually done on a shift schedule, once every eight hours or more frequently.

One more safety feature which would be built into all pipelines resulting from this proposal, according to industry spokemen, is that remotely operated mainline block valves will be provided at remotely controlled pipeline facilities in order to allow isolation of segments of the pipeline. Isolating valves are required by CFR 195.260 and remote operation of these valves, which is now voluntary, would be one of the primary objectives of a remote controlled pipeline facilities. Table 2 shows the relationship between the diameter of a pipeline and the volume contained per mile of line.

Table 2. LENGTH/VOLUME RELATIONSHIP OF LINEPIPE

Size (inches ID)	Length Required to Hold 1000 bbl. (miles)	Barrels Per Mile of Line
2.067	45.6	22
4.026	12.0	83
6.026	5.3	189
8.071	3.0	334
10.020	1.9	515
12.090	1.3	750
24.000	0.3	2954

e. Offshore Storage

Crude oil storage on the Gulf of Mexico OCS is, in general, limited to small volume (10,000 barrels or less) tankage on production platforms. There are still a few isolated instances where barges are used as floating storage with the oil moved to shore in transport barges. Also there is one 100,000 barrel platform mounted tank in the Ship Shoal area.

The storage tank used in conjunction with producing platform operations must comply with the safety and pollution control regulations of OCS Order No. 8 and specifically must be equipped with high-level shut-in sensors.

f. Timetable for Development of OCS Oil and Gas Leases

The length of time required to develop an OCS oil and gas lease is dependent upon many factors, some of which are:

(1) water depth

(2) distance from other producing fields

(3) number and depth of development wells required to justify a pipeline

(4) availability of drilling equipment

(5) climatic conditions (storms, ice, etc.)

For development of leases in "normal" water depths (up to 400 feet) on the Gulf of Mexico OCS it takes from 3 to 5 years to prove the reservoir by exploratory drilling, to fabricate and erect one or more platforms and to drill 15 development wells on each platform. One operator has estimated that it may take 10 years to develop one of the "deep water" (1200-1800 feet) tracts; however, this estimate assumed that there would be some delay because of known shortages of material and supplies.

To generalize, production from a fixed platform in 400-600 feet of water should be available 3 to 6 years after a field has been discovered and its size determined--at least enough to justify investment in development. For fixed platforms in 1000 feet of water the time may stretch to 8 years. Production from underwater completions in 1000-3000 foot water depths should be available in the mid 1980's.

The technology to drill in 3000 feet of water exists today; however there are only a limited number of drillships with this capability available, and new construction requires up to two years from order to delivery.

Development of the environmentally hostile areas of earthquake zones, heavy moving ice fields and unstable bottoms may require additional study by both industry and government before drilling operations are allowed to proceed.

A general description of how platforms are designed for these areas is found in section I.C.1.c.(1).

g. Terminations of Offshore Oil and Gas Operations

According to industry estimates, with proper placement of wells and sufficient pipeline capacity, a gas reservoir could be profitably drained in as little as 10 years. In contrast, some oil reservoirs have been produced for over 20 years in offshore areas. When the reservoir has been depleted to a level where it cannot be profitably produced, operations are terminated. During abandonment, the wells are plugged with cement, the casing severed at least 15 feet below the mud line, the platform removed, and all obstructions cleared from the area. All that remains is the pipeline system. Frequently, major trunklines can be used for future oil and gas production from adjacent areas, but smaller spur lines are abandoned in place. Pipeline abandonment consists of first purging the lines of entrained hydrocarbons by water flushing and then severing the ends below the mud line.

2. Offshore Oil and Gas Development Technology

a. Existing Commercially Feasible Technology

(1) Geophysical Exploration

Geophysical exploration tools and techniques continue to be improved as new electronic and computer capabilities evolve. The latest breakthrough is the "bright spot" techniques which gives a better indication of the existence of high gas and/or oil saturation.

(2) Exploratory Drilling

(a) Shallow Water Drilling Equipment

This equipment is now greatly refined over the first offshore drilling rigs. New equipment, particularly the jack-up's are quite mobile--some even self-propelled--with up-to-date automation and safety features. Some of the rigs now being delivered can drill to 30,000 feet in 300 feet of water.

(b) Deep Water Drilling Equipment

Floating drilling equipment is of two types: drillships and semi-submersibles. The drillships are preferred for wide-ranging exploratory work due to their higher transit speeds whereas semi-submersibles have much better stability during the actual drilling operations.

Anchoring systems for both types of rigs were restricted to about 600 feet of water until recently. Many rigs currently under construction are being equipped with 1000 foot mooring systems. This same depth (1000 feet) is also about the current limit of diver capability.

As mentioned in I.C.1.b.(2) one rig is currently (July 1974) drilling in 2100 feet of water, using a dynamically positioned drillship. Present water depth limitation is thought to be about 3000 feet; the limiting factors being the design of the drilling riser and the electrohydraulic systems for safe and reliable control of the subsea well head blowout preventors.

(3) Field Development

(a) Platforms

Computer assisted design techniques are at a stage whereby industry claims it is prepared to design and build a 1000 foot platform; a platform for 850 feet of water has been designed, a permit has been issued and is ready to start construction. At the present time, the maximum water depth feasible for a fixed bottom founded platform is determined by economics more than any other factor.

In areas with unstable bottom conditions, industry has developed designs that will jet the entire platform sub-base or template through the unstable sediments and then drive piles through the legs into the stable subsurface. Other design improvements use fewer but stronger vertical members which offer less resistance to mud flows and other potential movement of the unstable areas.

(b) Drilling

(i) Shallow Water

Development drilling technology for shallow water OCS development is the same as onshore drilling technology and as described in section I.C.1.c.(2).

(ii) Deep Water

Development drilling technology for deep water is the same as described in I.C.1.b. and I.C.1.c.(2) with the depth limitations imposed by platform depths I.C.2.a.(3)(a) or subsea completion capabilities.

(c) Completions

(i) Platforms

Well completions on platforms are essentially the same as at onshore locations. After the well has been drilled, cased, logged and perforated, and the tubing run and hung in the well head, mechanical bridge plugs are run and set in the tubing to close in the well. The BOP's are closed and the pressure in the well bled off to check that the bridge plugs are holding and the well dead.

Once it is certain that the well is dead, the BOP's are removed and a preassembled well head array of valves, chokes, gauges etc (known as the Christmas Tree) is installed and connected to the flow line ready to produce. Wells completed on the OCS are protected by redundant safety systems of fail-close valves. The tubing head valves are held open by hydraulic pressure and are spring loaded to close if anything disrupts the hydraulic operating system. When tubing head valves are closed (they of course may also be operated manually) the well pressure is directed in such a way as to abet the spring loading and help keep the valve closed.

Another safety feature on each well is the subsurface safety valve. This device is located in the tubing well below the elevation of the sea floor; the original ones were designed to close automatically when the producing rate exceeded a preset value. These "storm chokes" are subject to the cutting action of abrasive material, particularly in those wells which produce sand, and several failures have been reported. New completions where shut-in tubing pressures are less than 4000 psig are now required to use "Surface Activated Subsurface Safety Valves" which, like the well head valves, are kept open by hydraulic pressure controlled from the surface. If the shut-in tubing pressure exceeds 4000 psig either a surface or subsurface activated safety valve may be used. Also, whenever the tubing is pulled from old wells during workover operations, the old storm choke is replaced with the surface controlled subsurface safety valve. Many OCS wells are also equipped so that some minor repairs such as parafin scraping, changing gas lift valves and storm chokes can be accomplished with tools pumped down through the flowline.

(ii) Subsea

Subsea completions are described in section I.C.1.c.(3)(b). The "wet" tree has virtually unlimited water depth capability. "Dry" or encapsulated trees are limited by the capability of the diving bell or utility capsule which is now about 1200 feet. Subsea completions have surface controlled fail-close well head valves and most are equipped for through-the-flowline workovers. Surface controlled subsurface safety valves for subsea completions are in later stages of development.

(d) Production

(i) Platforms

Platform located production facilities are described in section I.C.1.c.(4).

(ii) Subsea

At this time (July 1974) there are no subsea production facilities, i.e. separators, pumps, compressors, installed on the U.S. OCS.

(4) Transportation of Oil and Gas

(a) Pipelines

Pipeline construction is described in section I.C.1.d.(2). At the present time, it is the opinion of the industry that it has the capability of laying 24-26 inch diameter pipe in water depths up to 500 feet; 12-18 inch diameter pipe in water depths up to 1200 feet and 8 inch diameter pipe in water deptys up to 2100 feet.

(b) Tankers and Barges

Tankers and barges which may be used on the OCS are described in section I.C.1.d.(1).

(5) Offshore Oil Storage

As mentioned in section I.C.1.e., there is very little offshore oil storage on the U.S. OCS, and no need or requirement is foreseen for new areas.

Underwater storage has been developed and installed in the Persian Gulf (three 500,000 barrel tanks) and the North Sea (a one million barrel tank). A floating barge of one million barrel capacity attached to a single point mooring in the Persian Gulf is used for floating storage.

(6) Oil Spill Prevention

(a) Drilling and Blowout Control

A blowout can occur when the formation pressure exceeds the weight of the mud column. If this over balance of the mud column is detected soon enough a blowout can still be averted by implementation of preplanned emergency procedures. This usually involves closing the blowout preventors and adding weight to the mud column by degassing and adding weight material, meanwhile circulating the mud under controlled pressure conditions.

Abnormal downhole pressures may be detected by monitoring the volume of mud in the tanks, change in drilling rate, or change in mud temperature. Systems are now available to monitor the mud tank volumes and temperatures directly at the drillers console. One other system that records pressures at the drill bit by impressing coded pulses on the mud column is now available commercially.

(b) Producing Operations and Workovers

The state-of-the-art of oil spill prevention on producing platforms is quite well developed. Automatic fail-close well head valves are available that can be actuated:

- manually
- remotely from several positions
- by high-low pressure sensors in flowlines
- by flame and smoke detectors

As a backup to the automatic well head valve there are also surface activated subsurface safety valves. Additional spill prevention is provided by the high-low pressure sensors and high-low volume sensors in separators, water knockouts and storage tanks. For workover operations, some of the repairs (paraffin scraping, pulling and replacing storm chokes and gas-lift valves) can be performed by tools pumped through the flowline (TFL) and thus obviate the necessity to kill the well, remove the tubing head vales and install blowout preventors--always a risky operation.

(c) Pipelines

Pipeline systems are protected by a set of automatic pressure sensing recorders in both ends of the system. These devices either shut down the flow automatically or sound an alarm to alert personnel of abnormal pressure levels. This is primarily a safeguard to limit the size of a spill in case of a catastrophic line break, since this detection system is insensitive to line pressure fluctuations up to 500 psi. Most oil is metered as it leaves the producing platform and again as it enters the onshore tank farm; thus attendant personnel can detect relatively smaller leaks by comparing inventory volumes (pumped vs. received) on a shift schedule, once every eight hours or more frequently.

Pipelines are also protected from corrosion by various coatings and by cathodic protective devices.

(7) Oil Spill Containment and Cleanup

(a) Containment

Oil spill containment capability is restricted to some type of a deployable boom arrangement. These systems are severely limited by wave height, wind velocity and current. Since one main factor in oil spill containment is time, some concessions in design and materials are necessary so the systems can be air deployable.

(b) Cleanup

There are two main cleanup techniques in use, mechanical gathering and sorbent recovery. The mechanical recovery systems are best suited to calm water and work better on heavy viscous crude than they do on light crude or products; however these systems continue to be improved and one containment system has been demonstrated effective in 8-foot seas, while a mechnical skimmer has operated effectively in 6-foot seas. Sorbent cleanup consists of spreading a sorbent material on the slick, mixing it with the oil then recovering the sorbent/oil mixture and disposing of it by burning or burying. Straw is a commonly used sorbent material.

(8) Drilling Waste Disposal

The major drilling "wastes" are drill cuttings and drilling muds. The weight and volumes of drill cuttings produced while drilling a 15,000 foot well on the Gulf of Mexico OCS is given in Table 1 in section I.C.1.c.(2) and amounts to about 1,000 tons per well.

The same table shows the amount of commercial mud additives ased in the same well. In the case of an exploratory well that is plugged and abandoned, the hole is left full of mud (below, between and on top of all cement plugs), and, after most of the barite has been recovered, the remainder is dumped overboard. On a multi-well platform, most of the mud is passed on from well to well; however, some mud is discarded overboard as each well is completed due to the need to recondition the mud occasionally.

b. Potential Future Commercially Feasible Technology

(1) Geophysical Exploration

The science- or art-of interpreting geophysical data is so highly competitive that new techniques do not become public knowledge until they are quite well developed. The latest innovation, the "bright spot" techniques, now gives some indication of the content of underground structures. With continuing developments in electronics and computer sicence, it is not beyond imagination that the capability to define stratigraphic traps will eventually evolve.

(2) Exploratory Drilling

(a) Shallow Water Drilling Equipment

Present mobile shallow water drilling structures are adequate for all U.S. OCS areas except those with unstable bottom conditions and those with seasonal and/or moving ice conditions. In the case of areas with unstable bottom conditions, drillships or semi-submersible rigs could be used for exploratory work.

The actual drilling equipment is the same for onshore, shallow water and deep water drilling. New technologies that may be developed in the future are, mainly, improvements and refinements of present day practices. These include:

- longer lasting bits to reduce number of bit changes
- direct reading of formation pressures at the drilling bit
- improved mud monitoring systems that can measure a sudden gain or loss of as little as one barrel in a 3000 barrel mud system
- continued improvement in automatic drilling technology

The only proposed radical departure from conventional drilling technology is an "Omnidirectional Drilling System" for which patents are pending but which has yet to be tested. To quote from the prospective patentee:

> "There is no possibility whatever of an oil leak into the water inasmuch as the surface of the subsoil, as the interface between the sea and the subsoil, is not pierced. The Omnidirectional Drilling System is a self-contained system capable of drilling along any curvilinear path and for any distance.
>
> The Omnidirectional Drilling System is able to drill for oil and natural gas in the subsoil of the sea directly from dry land without in way going through the sea itself."

(b) Deep Water Drilling Equipment

All of the discussion in the preceeding section I.C.2.b.(2)(a) apply also to deep water drilling equipment. In addition, the future will see improvements in the following areas to permit drilling in deeper waters:

- improved mooring systems
- improved riser support systems

- improved dynamic positioning systems
- improved reentry techniques and equipment
- improved control systems for the subsea well head BOP's

All of this should allow the present drill ships and semi-submersibles to move at least to the 3000 foot water depth area and perhaps deeper.

The Tension Leg Platform (TLP) is scheduled for sea tests in early 1975. The TLP will be a buoyant structure held in place by tensioned vertical-anchor cables. Buoyant vertical colums extending upward from submerged horizontal cylinders will support a working deck well above the water surface. The advantage of the TLP would be that the incremental cost for additional depth would only be the cost of anchor cable. Although being designed primarily as a development drilling and production platform, it could be used for wildcat drilling in deep areas.

(3) Field Development

(a) Platforms

Plans are now complete for a platform to be erected in 850 feet of water in the Santa Barbara Channel. Industry feels that it is possible to build a safe platform in 1200 feet of water in the Gulf of Mexico. The technology exists to design platforms for almost any water depth; the maximum feasible water depth is determined primarily by economics.

he TLP as described in I.C.2.b.(2)(b) appears to be a reasonable prospect as an economically justificable deep water drilling and production platform for the near future.

(b) Drilling

All of the discussion in section I.C.2.b(2 pertains equally to this section.

(c) Completion

(i) Platform Completions

The basic systems and tools for well completion are not expected to change in the foreseeable future; however there will be a continuing effort to improve reliability of all parts of the system and thus improve safety standards. Future improvements in automation should also improve safety records by reducing the opportunities for human error.

(ii) Subsea Completions

As described in section I.C.2.a.(3)(c)(ii) subsea completion technology exists to about 1200 feet of water.

To go beyond diver capability (approximately 1000-1200 feet) with "wet tree" completions requires the development of automatic or remote operated flowline connectors. It is expected that this technology will be developed for 3000 feet of water before economic reserves have been proven at those water depths.

Encapsulated well completions are limited by shell thickness and strength of the capsule; all other parts of the completion are identical with platform or onshore completions and thus will profit from any advancements in those areas. One limitation again is the connection of flowlines beyond diver capability; however, with the encapsulated tree, there is the possibility of pulling the flowline through a packing gland to where the connection can be completed by non-diver personnel inside the one-atmosphere chamber.

(d) Production Facilities

(i) Platform Located

Improvements in platform located production facilities will follow the same trend as those for platform completions; the emphasis will be for more automation and more reliable sensing and detection systems.

(ii) Subsea Production Facilities

Some subsea systems are now either undergoing tests onshore or being prepared for installation and testing in shallow water. As these move into water beyond diver capability, they will require remote operated manipulators to switch wells for testing, directing TFL tools, operating pumps, compressors, etc. Gas compression and/or a two phase pumping system are two necessary components of a susbsea production system that have yet to be solved.

(4) Transportation of Oil and Gas

(a) Pipelines

New technology for pipelines will be directed toward faster and more economical lay barges and pipelaying procedures. It is expected that pipelaying techniques will advance into deeper and deeper water concurrently with drilling and completion capabilities.

(b) Tankers and Barges

The use of tankers and barges on the U.S. OCS is expected to be severely restricted and limited to transportation of small volumes produced while testing wells to determine size and extent of reserves before commencing a field development program. New technologies for tankers are, of course, advancing rapidly worldwide. Advancement is noticeable mainly in size but is equally progressive in the forms of double bottoms, segregated ballast systems and limiting the maximum size of individual tanks or compartments.

(5) Offshore Oil Storage

Like tankers and barges, there is little offshore storage anticipated for the U.S. OCS.

(6) Oil Spill Prevention

(a) Drilling

Many of the new technologies described in sections I.C.2.b.(2)(a)&(b) are directed toward well control and blowout prevention--thus are also oil spill prevention techniques.

(b) Completions

Improvements in the reliability of surface operated subsurface safety valves as well as the fail-close tubing head valves will contribute to reduced oil spills.

(c) Production Facilities

No radical departure from present production facilities is anticipated in the future. New developments will be in the field of automation and fire and smoke detection devices.

(d) Pipelines

Improvements in the mass flow monitoring systems will allow faster response to a major pipeline break.

(7) Oil Spill Containment and Cleanup

No new technology is anticipated in the field of oil spill containment and cleanup.

(8) Drilling Waste Disposal

No new technology is anticipated in the field of drilling waste disposal. The only drilling wastes are drill cuttings and drilling mud. The only alternative to discharging these wastes into the sea is to haul them ashore and dispose of them there.

D. Other Management and Supervisory Aspects of the Program

1. Management Requirements Before Onset of OCS Operations

a. Preparation of Individual Sale Environmental Impact Statements (Site-Specific Statements)

Each individual sale proposal under the accelerated leasing program will require an environmental impact statement under section 102(2)(c) of the National Environmental Policy Act of 1969. The Bureau of Land Management will continue to prepare these statements using generally the same procedures as are currently followed. These procedures begin with the selection of a geographic area in which a lease sale is proposed to be held. Summary resource reports in that area are requested from the U. S. Geological Survey (USGS) and the Fish and Wildlife Service (FWS), and the National Marine Fisheries Service (NMFS). These summary resource reports are mainly used for tract selection purposes, but are also used as information sources for the draft impact statement. Other information sources (published literature, research in progress, contract research reports, and personal contact with scientists in the area) are utilized in preparing the impact statement. In general, the statements describe in considerable detail the physical and biological environments in the area (both offshore and onshore), the coastal socio-economic conditions, the hydrocarbon resource potential of the sale, the primary and secondary impacts of the lease sale on the environment and economy, and a matrix analysis of each tract being offered for the possible impact of structures and oil spills that could ensue from development of that tract. After the draft impact statement is prepared and reviewed within the Department of Interior, it is made available to the public for a minimum of 30 days before a public hearing on the proposed action is held. Review and comments are specifically requested from the following Federal agencies:

- Geological Survey
- National Park Service
- Fish and Wildlife Service
- Bureau of Outdoor Recreation
- Bureau of Mines
- Army Corps of Engineers
- Environmental Protection Agency
- Department of Transportation
- Federal Power Commission
- Energy Research and Development Administration
- Treasury Department
- Department of Commerce (viz. National Marine Fisheries Service)

Review and comment is also solicited from affected State(s) agencies, as well as being requested from any other interested parties. Comments supplied by solicited agencies, oral and/or written testimony from the public hearings, and other public comment are incorporated into the final environmental impact statement. Special emphasis is placed on identifying highly valued sites (e.g. shipwrecks, wildlife refuges, reefs) and habitats (fishing areas, marshes) that could be severely affected by normal operations or accidental oil spills, and on identifying specific problems that would increase the risk of exploration and development operations (e.g., unstable bottom conditions). These sites or problems may then be mitigated in several ways. The Secretary of the Interior may withdraw tracts from the sale, postpone the sale, or impose special stipulations on operations in tracts located near highly valued sites or in problem areas. The final impact statement must be available to the public at least 30 days before a decision can be made and the proposed action can be undertaken. A minimum of 90 days must elapse between the time the draft statement is made available and the time the action can begin.

Concurrent with final EIS preparation and public review, a program decision option document (PDOD) is prepared which presents the economic and technical information developed independently of the environmental assessment of the proposal. This PDOD will be an important tool used by the Secretary in arriving at a decision on the future of the OCS oil and gas program.

b. Pre-Sale Evaluation

The U.S. Geological Survey calculates the resource value of each OCS tract, with BLM performing an audit and review function. In calculating the resource value for each tract, GS is responsible for collecting and analyzing geologic, geophysical, and engineering data which may be either purchased from contractors and/or obtained from industrial sources. The data analyzed by GS is then fed into a computer program that yields a mean value that has been generated by a range of values method. The various parameters include a minimum, maximum, and most probable of the following which varies between individual tracts: productive areas, oil acre ft./total acre ft., gas reservoir life, oil reservoir life, net pay (ft.), recovery factor-oil (fraction of oil in place (OIP) or stock tank barrels (STB/acre ft.)), initial STB/day/stream, initial MCF/day/stream, years to production, gas-oil ratio standard cubic feet (SCF)/STB, STB condensate/MMSCF. The following parameters were assigned a constant minimum, maximum, and most probable value for each tract: $/STB (except for drainage tracts), current $/MCF, tax as a fraction of gross income, inflation factor for operating costs (1972=1.0), value is used for each tract for porosity, water saturation, and oil formation volume factor as bbl./STB.

The above values assigned to these parameters are fed into a range of values (ROV) computer program: the ROV will generate 500 values for each tract the mean of which is taken to be the resource value of the tract. The ROV program, which has only been used for Gulf of Mexico sales, is run by GS-New Orleans (NO), and they are responsible for the inputs and values assigned the parameters. BLM coordinates with GS-NO on the values to be used for the price of oil, gas, and discount rate.

After GS-NO has evaluated the tracts and the ROV is complete, a pre-sale evaluating team composed of staff members from BLM-WO and BLM-NO reviews and audits the Geological Survey's product. This function is commonly done one week before a lease sale.

c. Selection of Bidding System

In choosing a bidding system for OCS sales, the Department of the Interior considers the six following broad categories of objectives:

(1) timing of resource discovery
(2) timing of resource production
(3) efficiency of recovery
(4) environmental protection
(5) competitive structure of the oil and gas industry
(6) government revenues, i.e., receipt of fair market value

All of these factors are weighed carefully, though changing national priorities often shift the emphasis placed on these various objectives. However, even when national priorities and the corresponding objectives are clearly identified, picking the bidding scheme which most closely conforms to those objectives is often a difficult task. There are two explanations for this difficulty. Very little is known about decision-making behavior under uncertainty, especially for the risk-averse firm. Since the OCS is an environment of extreme uncertainty and since the firms competing for OCS leases are risk averse, the need for additional research in this theoretical area seems clearly established. A second problem that arises in selecting the most appropriate bidding scheme involves the trade-off among objectives. Frequently, government decision-makers must confront questions like: How much of a sacrifice in terms of receipt of fair market value are we willing to make in order to achieve improvements in efficiency of resource recovery? The dilemmas presented by questions such as these are not easily resolved.

Selecting the most appropriate bidding scheme is and will continue to be a formidable task. However, increasing interest in the difficulties of OCS development should hasten the advent of the expertise needed to resolve these problems.

An OCS sale #36, was held in October, 1974, in which 10 tracts were offered for sale on the basis of competitive royalty bids and with fixed cash bonus. Provisions for royalty reductions after production has been on stream for a minimum of one year have been included in the sale regulations. The impact of royalty bidding and sale of royalty tracts on the exploration and development of offshore leases will not be known for some time.

d. Lease Sale

After tracts have been selected for a given proposed sale, a draft impact statement prepared and disseminated for review and comment, and public hearings are held, a final impact statement is prepared and disseminated. After the final EIS has been completed a Program Decision Document (PDOD) is prepared for the Secretary. This document summarizes the hydrocarbon resource benefits which would be expected to come from leasing and subsequent development. It also summarizes the environmental risks and hazards. It typically presents the Secretary with the options of whether or not to lease at all, whether to withdraw certain environmentally hazardous tracts from the lease sale area, and whether or not to require special stipulations on certain tracts for environmental protection purposes. Other options may also be included, depending on the specific issues pertaining to the lease sale area. The Secretary then makes the final decisions on all the issues posed.

When a decision made to proceed with the sale in some form, leases are let on the basis of competitive bidding. After the final statement is released, a sale notice is published in the Federal Register. The sale must be held at least 30 days after the sale notice. Sales are conducted by sealed bid, and the Secretary has the discretion of conducting the sale on a cash bonus-fixed royalty (not less than 12½%) basis, or on a royalty-fixed bonus basis. All OCS lease sales to date have been conducted on a cash bonus, fixed royalty (16 2/3%) basis, although the recent

Louisiana #36 sale just mentioned included 10 tracts offered on a royalty basis as a test of that system.

At a lease sale, which is open to all those desiring to attend, the tracts are treated sequentially using the tract numbering scheme for that sale. All the bids on a given tract are opened, the company(ies) biding is (are) identified aloud, and the amount of the total bid and the per acre figures are read aloud. No subjective judgments are made (e.g. indicating the high bidder); the certified checks or bank drafts accompanying the bids and the bids themselves are recorded. The amount of the check or draft is required to be one-fifth (20%) of the cash bonus bid. Running totals are kept of the dollar amounts bid and the dollar amount of apparent high bidders. No decisions or awarding of leases is done at this time.

e. Post-Sale Evaluation

Post-sale evaluation is conducted to determine the highest responsible qualified bidder for each tract, and to ensure that the Federal Government receives fair market value for each tract bid upon. A matrix is constructed for each tract which depicts several categories of information about the tract. Three values entered in the matrix are of most importance. The first is the mean of the range of values (ROV), which is the USGS presale estimate of the value of the tract. A second value is the mean of the ROV discounted 10% per year for two years. This is entered because a tract for which a high bid is rejected may not be re-offered for lease until final disposition of any appeal that may be filed. In the past, these appeals have required a minimum of two years to process, and thus the mean value is discounted to reflect the present value loss to the Government.

A third value for consideration is the average evaluation of the tract. This is calculated by summing all bids on the tract plus the Government's presale value and dividing by the total number of bids plus one. The significance of the average value increases with an increased number of bids on a given tract.

These values together with an analysis of the sale competition are used by the OCS Manager in deciding whether or not to accept a bid. The major components for analysis of sale competition are: average number of bids per tract by type of tract, the bidding performance of the high bidder by quarters, the average number of bids on tracts on which the high bidder bid, and per acre bids on adjoining and nearby tracts.

Types of tracts are divided into drainage, development, and wildcat tracts. The three types of tracts are separated in determining averages because drainage tracts (those whose reservoir(s) are being drained by production of an adjacent tract) typically receive fewer bids than the other two types; this might distort the average if all tracts were considered together.

The bidding performance of high bidder by quarters shows how many times the high bidder on the tract in question bid at the sale, and where this bid ranked in relation to other bids on tracts of interest. The average number of bids on tracts on which high bidder bid shows the level of competitive interest for tracts bid on by all high bidders. These two values are used to evaluate bidding strategy.

There are other components of the post sale matrix which allow some determination of environmental impact and orderly resource development. However, environmental considerations are made in earlier phases of each OCS leasing action. Tract reserves, leasing history of the tract, and status of production in the area are considered for the orderly and timely resource development.

2. Proposed Supervisory Procedures for OCS Resource Development

a. OCS Operating Regulations

Regulations governing OCS oil and gas lease operations in the Gulf of Mexico are contained in Title 30, Code of Federal Regulations (See Attachment A). These regulations will be applied, with the then current amendments and additions, to other geographic areas. Leasing regulations are contained in Title 43, Code of Federal Regulations (See Attachment A). The regulations established procedures and requirements to be followed in all stages of lease operations: exploration and development, drilling, production, transportation (pipeline construction and operation) and abandonment.

A general description of operating requirements under the existing regulations follows:

a. Plans: Operating plans must be submitted by the operators and approved by USGS through the Oil and Gas Supervisor before each stage of operations is initiated (exploration, development, abandonment). Approval of all operations must be obtained prior to their commencement.

b. Operator Inspection and Testing: The operator is required to inspect all aspects of the safety systems at specific intervals, e.g., daily pollution inspection on manned facilities, "frequent" inspection on unmanned facilities, monthly test of check valves. Detailed records of inspections and tests are required.

c. Reports: The operator is required to report all spills or leakage of oil to USGS without delay. He is also required to notify USGS of any unusual condition, problem or malfunction within 24 hours (30 CFR 250.45)

d. Safety Devices: Required safety devices include subsurface safety devices, high-low pressure shut-in controls, high liquid level shut-in controls, pressure relief valves, automatic fail-close valves at the well head, automatic fire fighting systems, automatic gas detector and alarm systems, and other safety devices on production equipment; high-low pressure sensing devices and automatic shut-in valves on pipelines; and blowout preventers, related well control equipment, and mud system monitoring equipment on drilling wells.

e. Waste Disposal: The lessee is prohibited from disposing into the ocean any oil (except that oil in produced formation water must average no more than 50 ppm), untreated waste material or other materials which may be harmful to aquatic life or wildlife. Any drilling mud which may contain toxic substances must be neutralized before it can be dispersed in the ocean. Waste disposals must comply with the 1972 Amendments of the Federal Water Pollution Control Act. Permits for disposals must be obtained from EPA under the National Pollutant Discharge Elimination System. Sewage samples shall be collected semi-annually by lessee personnel and the samples submitted to a laboratory for analysis. Results of the analysis will be available on the platforms and rigs for inspection by the USGS technicians. USGS personnel are responsible for enforcing the requirement but do not take the samples.

f. Site Clearance: When an installation is no longer needed for development of the lease, the well is plugged with cement and all casings and piling must be severed and removed to at least 15 feet below the ocean floor and the location must be dragged to clear the site of any obstruction.

g. Debris: Regulations and OCS Orders prohibit the disposal of debris into the Gulf of Mexico. Solid waste must be either incinerated or transported to shore for disposal in accordance with applicable requirements under State and Federal law.

h. Contingency Plans and Equipment: The operator is required to have an approved plan for controlling and removing pollution which provides for:

(1) Standby pollution control equipment, including containment booms, skimming apparatus, and approved chemical dispersants immediately available to the operator at a land-based location.

(2) Regular inspection and maintenance of such equipment.

b. OCS Orders

OCS Orders derive their authority from 30 CFR 250 and carry the weight of the original OCS regulations. They are issued by the USGS and are, in general, more specific, technical requirements than the regulations, and are designed to specifically define the responsibilities of offshore operators and methods of operating. At the present time, operating orders have been developed and are in use only for the Gulf of Mexico and Pacific (Calif.) OCS areas. The intention to prepare operating orders for the Gulf of Alaska was announced by USGS on August 1, 1974; no specifics were given except the operations that should be addressed. After receipt of comments, the USGS proposed a set of operating orders on January 6, 1975 and again requested public comment. As of this time, operating orders for the Gulf of Alaska have not been finalized.

The current operating Orders address several different aspects of operations, were developed over several years (1969-1972), and are constantly undergoing review within USGS for possible amendments. (A proposed modification of OCS Order No. 8 was published in the Federal Register on January 21, 1975). Gulf of Mexico Orders are found in Attachment B; several of these are identical for the Pacific, but the [illegible]s unique to the Pacific are also found in Attachment B.

c. Inspection Programs - Approval Requirements

Evidence of compliance with the regulations, orders, and other lease requirements is obtained through surveillance of the operations under the lease and enforcement of specific requirements. The inspection system of the Geological Survey includes: (1) review and approval of plans before each operating stage is initiated, (2) review and follow-up as necessary, by USGS inspectors, of all reports required of the operator by the regulations and orders, (3) on-site inspection and (4) aerial monitoring through the use of helicopters (operators are also required to inform each other of oil spills or other irregularities which they observe).

a. Operator reports: A comprehensive reporting system covering all oil spills and any unusual conditions (for example: reporting and investigation of a persistent oil slick from an unknown source such as a sunken ship or natural oil seep) is required by the orders and is a key factor in monitoring operations. Operators are also required to maintain records for USGS inspection of required periodic tests of safety equipment. Compliance with reporting requirements can be assured only by periodic on-the-site inspection and aerial monitoring.

b. On-Site Inspection: During the course of drilling, all operations are inspected at least one time. Leases in certain areas of the Gulf of Mexico or in a particular development stage may require more inspections to assure the achievement of safety objectives. USGS is continuing the systematic inspection program and a more stringent enforcement policy. This has resulted in increased operator compliance along with greater coverage of production operations and better documentation of inspection results.

A complete drilling inspection is normally conducted on each drilling rig approximately every six weeks. Random inspections may be made more frequently. Depending on the number of drilling rigs in each District, the frequency of inspections on a rig may vary from six to twelve per year. All producing platforms are inspected at least once a year and random inspections are made more frequently on some. The frequency rate for platform inspections is approximately once every nine months.

Listed below are the results of on-site inspections performed in response to the observations made during pollution surveillance flights conducted from December 1, 1972 through January 31, 1974:

Pollution Inspections	No. Platforms	No. Wells	Warnings	Suspensions
49	144	962	31	20

A program of intensive inspections is used on OCS leases. Periodically, all available inspectors devote a week to a special inspection, whereupon production platforms and drilling wells are inspected on a random basis; inspections during other periods are conducted on a regular basis with emphasis on operations believed to require special attention. The USGS inspector force in the Gulf of Mexico has increased from 7 technicians and 5 engineers as of July 1, 1969 to 28 technicians and 15 engineers as of January 31, 1974. During the period November 1, 1972 through January 31, 1974, technicians spent 4,188 inspection days or 34,893 man-hours, and engineers 452 inspection days or 3,614 man-hours in the field. Detailed inspections were conducted on 1,235 major producing platforms and 991 minor platforms (out of a total of 2000) in the Gulf of Mexico from December 1, 1972 through January 31, 1974. Also, during this time period, 813 inspections of single-wells or satellites were made by boat. Approximately 60% of these inspections were unannounced. Included in these inspections were 13,821 well completions. Also, during this time period, 1,311 inspections of drilling rigs were conducted. As of January 31, 1974 in a total of 11,383 holes, there were 9,691 completions capable of producing oil and gas on the OCS lands offshore Louisiana and Texas, not including service completions. Approximately 65 drilling rigs were operating in Gulf of Mexico OCS waters at the end of January, 1974.

c. Aerial Monitoring: "Fly-overs" of the OCS operating areas are programmed on a nearly daily basis by USGS inspectors. Any indications of oil pollution or other non-compliance is followed immediately by an on-site inspection.

During the period January 1 through September 30, 1973, 1,106 pollution surveillance flights were made. The helicopters chartered by the Geological Survey for use of the inspecting personnel flew a total of 4,088 hours.

d. Enforcement

The enforcement policy is intended to: (1) reduce the frequency of non-compliance with lease requirements which may lead to loss of life, loss of property, or damage to the environment; and (2) maintain uniform enforcement standards to be applied to all operations affecting OCS lands in the Gulf of Mexico. When, in the course of an inspection, a requirement pertaining to the prevention of oil pollution or any other safety hazard is found to be in non-compliance, the operation will be shut-in until it is brought into compliance. After a shut-in, the operation can only be assumed by authorization of the USGS; in all cases, this requires reinspection or a waiver of the inspection requirement. Minor incidents of non-compliance may require only a warning that corrections be made within a week. The operations will be shut-in if the required corrections are not made.

Additional penalties for non-compliance are specific in P.L. 83-212, Outer Continental Shelf Lands Act, Sec. 5(a)(2). "Any person who knowingly and willfully violates any rule or regulation prescribed by the Secretary for the prevention of waste, the conservation of the natural resources, or the protection of correlative rights shall be deemed guilty of a misdemeanor and punishable by a fine of not more than $2,000 or by imprisonment, and each day of violation shall be deemed to be a separate offense." Also Sec. 5(b)(1) and (2) provide for cancellation of non-producing and producing leases by notice subject to judicial review or appropriate judicial proceedings.

The following tables (Tables 3-5) indicate equipment malfunctions detected during inspections and enforcement actions over three separate periods. Minor incidents of non-compliance result in formal warnings while incidents of non-compliance of a potentially more hazardous nature result in well or platform shut-ins until the operation is in full compliance with regulations and orders.

These tables indicate specific items found to be in non-compliance during special inspections. Basic pollution control items of production equipment in which malfunctions were detected for the time periods identified are as follows:

Table 3. EQUIPMENT MALFUNCTION DETECTED DURING JANUARY THROUGH NOVEMBER, 1971 SPECIAL INSPECTIONS

	No. Checked	Operable	Inoperable or not within acceptable tolerance	Percent Failure
Surface Safety valves	2392	2306	86	3.6%
Flowline sensors	4166	4081	85	2.0%
Check Valves	2222	2052	170	7.7%
Pressure vessels				
High pressure sensors	908	875	33	3.6%
Low pressure sensors	765	744	21	2.8%
Low level shut-in	511	481	30	5.9%
High level shut-in	460	439	21	4.6%
Total	11,424	10,978	446	3.9%

Table 4. EQUIPMENT MALFUNCTION DETECTED DURING JANUARY THROUGH NOVEMBER, 1972 SPECIAL INSPECTION

	No. Checked	Operable	Inoperable or not within acceptable tolerances	Percent Failure
Surface Safety Valves	1,492	1,423	69	4.6%
Flowline sensors	1,327	1,290	37	2.8%
Check Valves	1,469	1,385	84	5.7%
Pressure Vessels				
High pressure sensors	1,100	1,077	23	2.1%
Low pressure sensors	784	771	13	1.7%
High level shut-in	405	398	7	1.7%
Low level shut-in	383	375	8	2.1%
Total	6,960	6,719	241	3.5%

Table 5. EQUIPMENT MALFUNCTIONS DETECTED JANUARY THROUGH SEPTEMBER, 1973 SPECIAL INSPECTIONS

	No. Checked	Operable	Inoperable or not within acceptable tolerances	Percent Failure
Surface safety valves	1,188	1,131	57	4.8%
Flowline sensors	385	378	7	1.8%
Check Valves	1,170	1,092	78	6.7%
Pressure Vessels				
High pressure sensors	857	841	16	1.8%
Low pressure sensors	521	514	7	1.3%
High level shut-in	217	212	5	2.2%
Low level shut-in	258	251	7	2.7%
Total	4,596	4,419	177	3.9%

It can be seen that over the 3-year period, detected malfunctions (as percent failure) have declined slightly in most categories, but not enough to state that more advanced technology or greater compliance is significantly reducing the risk of spills in the offshore environment.

Surface operated subsurface safety valves are periodically pulled from the wells and checked. This requires removing the valve from the well to inspect and repair or adjust as necessary and reinstall. One company utilized test stands to test the valves performance characteristics under simulated flow and pressure conditions. Surface operated subsurface safety valves are tested in place by releasing hydraulic pressure within the closed system to close the valve and repressuring to open. An average reporting period from May 1973 through July 1973 resulted in approximately 3,000 subsurface safety valves being checked. Of this amount there were 394 failed components detected in the valves but a number of the valves had more than one failed component.

Companies fined in District Court for failure to install subsurface safety devices in offshore oil wells during 1970 in the Gulf of Mexico are presented below. Each company entered a plea of nolo contendere. The maximum fine for violation of the Outer Continental Shelf Lands Act is $2,000 per count, each day being a separate count.

MAXIMUM FINES

Chevron Oil Company	$1,000,000
Gulf Oil Company	250,000
Tenneco	32,000
Kerr-McGee	20,000
Mobil	150,000
Continental	242,000
Humble	300,000
Shell	340,000
Union of California	24,000
	$2,358,000

The total number of warnings and suspensions ordered for infractions of OCS Orders which occurred during normal inspections from December 1, 1972 through January 31, 1974, are as follows:

WARNINGS			SUSPENSIONS		
Drilling	Workover	Production	Drilling	Workover	Production
35	3	2,164	15	4	1,198

No date for direct comparision of pollution incidences for similar time periods before and after the current "more stringent enforcement policy" are available. This "policy" is difficult to reconcile with the decline in the number of inspections made on different pieces of equipment from 1971 to 1973 (See Tables 3-5). However, experienced personnel, private and government, are aware that after public attention was focused on the oil spill at Santa Barbara in January 1969, there has been a great deal less oil pollution in the Gulf from normal oil and gas producing operations. The public awareness, concern, and demand to prevent pollution has been a major factor in the reduction of oil spills.

In the past, major events were catalogued, but less serious events were often not reported. Occasionally, some years ago, wells were even intentionally flowed into the water for short periods during cleanup operations. Now, burning devices are designed to consume this well clean-up oil without air or water pollution. More automatic equipment is now in use to shut-in production whenever a leak occurs in pipeline or production facilities. These include, but are not limited to, pressure sensors and high and low level controls. Drip pans are placed under valves, vessels, and the production system to prevent leaking oil from escaping into the waters of the Gulf.

New reporting and investigative procedures established in the last two years have increased many fold the number of pollution incidents reported as well as the time spent by USGS personnel in surveillance flights by helicopters in assuring proper documentation of pollution events.

There have been several detailed studies recently completed concerning operating practices on the OCS. The Department's response to these studies and the steps being taken at this time will improve many facets of OCS management practices. These studies are discussed in a later section of this statement.

e. Contingency Plans for Oil Spills

Oil spills will occasionally occur as a result of natural disasters, equipment failure or human error. In the event that such an emergency occurs, the following actions will be taken:

(1) Requirements of OCS Order No. 7 1/

In the case of any spill, the operator is required to initiate action to control or remove the oil pollution in accordance with his approved emergency plan. In any case, a spill or leakage of less than 15 bbls. requires a report from the operator as to the nature of the spill or leakage, why it occurred and what steps were taken to correct it. A spill of 15-50 bbls. must be reported by telephone immediately to USGS and confirmed in writing. A spill of over 50 bbls, or one of any magnitude that cannot be immediately controlled, must be reported immediately to the Coast Guard and the Environmental Protection Agency as well as to USGS.

(2) Regional or National Contingency Plans

If the operator should be unable to control and remove the pollution, the Regional or National Oil and Hazardous Substances Pollution Contingency Plan may be activated and the designated Federal On-Scene Coordinator would direct control and

---

1/ See Attachment B.

clean-up operations at the operator's expense. This has never been necessary in the case of any spill on OCS lands.

The Regional or National Oil and Hazardous Substances Pollution Contingency Plan was developed pursuant to the provisions of the Federal Water Pollution Control Act as amended (33 U.S.C. 1101). (EPA has published the revised National Oil and Hazardous Substance Pollution Contingency Plan as requird by the Federal Water Pollution Control Act Amendments of 1972.) Section 11(c)(2) of that statute authorizes the President, within sixty days after the sections becomes effective, to prepare and publish such a Plan. The Plan provides for efficient, coordinated, and effective action to minimize damage from oil (and other) discharges, including containment, dispersal, and removal. The Plan includes (a) assignment of duties and responsibilities, (b) identification, procurement, maintenance and storage of equipment and supplies, (c) establishment of a strike force and emergency task forces, (d) a system of surveillance and notice, (e) establishment of a national center to coordinate response operations, (f) procedures and techniques to be employed in identifying, containing, dispersing and removing oil, and (g) a schedule identifying dispersants and other chemicals that may be used in carrying out the Plan, the waters in which they may be used, and quantities which may be safely used. Annex X of the Plan basically sets forth a no dispersant policy. Exceptions can be made for safety reasons (to prevent fire or explosions) or for certain other circumstances such as the protection of endangered waterfowl. However, the approval of EPA is required, except in case of safety when the approval of the On-Scene Coordinator is required. The Plan will be revised from time to time as necessary. Operation of the National Contingency Plan requires a nationwide net of regional contingency plans. Guidelines for that nationwide net are established in the National Plan. This plan provides for a pattern of coordinated and integrated responses to polluting spills by departments and agencies of the Federal Government. It establishes a national response team and provides guidelines for the establishment of regional contingency plans and response teams. The Plan also promotes the coordination and direction of Federal, State, and local response systems and encourages the development of local government and private capabilities to handle such pollution spills.

The Plan is effective for all United States navigable waters including inland rivers, Great Lakes, coastal territorial waters, and the contiguous zone and high seas beyond this zone where a threat exists to United States waters, shoreface, or shelf-bottom. Its provisions are applicable to all Federal agencies. The Plan is operative nationwide.

A memorandum of understanding between the Departments of the Interior and Transportation outlines the respective responsibilities of the Geological Survey and the Coast Guard under the National Contingency

Plan. USGS is responsible for the coordination and direction of measures to abate the source of pollution when the source is an oil, gas, of sulphur well. This responsibility includes the authority to determine whether pollution control operations within a 500 meter radius of the pollution source should be suspended to facilitate measures to abate the source of pollution. The Coast Guard is responsible for coordination and direction of measures to contain and remove pollutants, and shall furnish or provide for the On-Scene Coordinator authority and responsibilities as provided by the National Contingency Plan.

(3) Petroleum Industry Contingency Actions

(a) Inventory of Known Resources Available for Emergency Oil Spill Control and Clean-up

From the upper Texas Coast to the Mississippi Delta region offshore operators maintain a large inventory of various kinds of equipment that could be put to use on short notice for containing and cleaning up an oil spill and killing the source of the spill. This inventory includes 177 boats ranging from 30 foot crewboats to 165 foot utility and cargo vessels, 64 helicopters, 103 fixed-wing aircraft.

(b) Clean Gulf Associates

Clean Gulf Associates is a non-profit organization formed by thirty-three companies operating on the OCS in the Gulf of Mexico. Their purpose is to provide for a stockpile of oil spill containment and clean-up materials for use by member companies in offshore and estuarine areas. Clean Gulf Associates has contracted, effective August 1, 1972, with Halliburton Services to supply equipment, materials and personnel necessary to contain and clean-up spills in the Gulf of Mexico to the limits of the OCS lying offshore and seaward of the States of Texas, Louisiana, Mississippi, Alabama, and Florida. Before any drilling commences in this area, an inventory of pollution combatting equipment would be stockpiled at a stragetic location. Should oil reservoirs be found and production ensue, a permanent base for containment and clean-up equipment will be established.

At the present time, Halliburton maintains four types of recover/clean-up systems for development at two primary bases located at Intercoastal City, and Grand Isle, Louisiana, and a sub-base at Venice, Louisiana and include:

(1) Fast response open sea/bay skimmer system
(2) High volume open sea skimmer system
(3) Shallow water skimmer system
(4) Auxiliary shallow water and beach clean-up equipment.

This type of organization must be established in any frontier area before exploration begins. Clean Seas is a similar group in California that can be geared up, should that area be re-opened for leasing.

f. Liability for Oil Spills

OCS Order No. 7 indicates quite clearly that the liability for oil spills rests entirely with the lessee.

> (b) If the waters of the sea are polluted by the drilling or production operations conducted by or on behalf of the lessee, and such pollution damages or threatens to damage aquatic life, wildlife, or public or private property, the control and total removal of the pollutant, wheresoever found, proximately resulting therefrom shall be at the expense of the lessee. Upon failure of the lessee to control and remove the pollutant the supervisor in cooperation with other appropriate agencies of the Federal, State and local governments, or in cooperation with the lessee, or both, shall have the right to accomplish the control and removal of the pollutant in accordance with any established contingency plan for combating oil spills or by other means at the cost of the lessee. Such action shall not relieve the lessee of any responsibility as provided herein.
>
> (c) The lessee's liability to third parties, other than for cleaning up the pollutant in accordance with subsection (b) above, shall be governed by applicable law.

g. OCS Regulations of Other Federal and State Agencies

Regulation and supervision of OCS oil and gas operations is not strictly a BLM-USGS responsibility, but rather a multi-agency network of responsibilities (sometimes overlapping) that attempts to give those agencies with particular expertise or historical responsibility in different facets of the marine environment control over those functions. These responsibilities are addressed below.

(1) Department of Transportation

(a) U. S. Coast Guard

The responsibilities of the Coast Guard are as follows: 1) insuring that structures on the OCS are properly marked to protect navigation (lights-number, arrangement, and power; identifying numbers on structure - size and location); 2) establishing and enforcing safety regulations on these structures; 3) maintaining surveillance during all cruises and overflights of the OCS for spilled or discharged oil; 4) inspecting and certifying all floating drilling rigs except those which rest on bottom during drilling.

(b) Office of Pipeline Safety (OPS)

The OPS has general responsibilities for pipelines. It primarily supervises gas pipeline safety, including the establishment of design criteria directed toward increased safety.

(2) Environmental Protection Agency (EPA)

The EPA has several functional responsibilities in the OCS leasing program. It is directly involved in the critical review of the draft environmental impact statement, for which it provides extensive, substantive comments. EPA also has a system whereby all draft impact statements are rated for adequacy, and it has recently instituted a policy of reviewing all final statements, but without rating them for adequacy.

The EPA is also required by Section 403 of the Federal Water Pollution Control Act (FWPCA) Amendments of 1972 to establish standards under which a permit for discharge of pollutants into navigable waters of the U. S. may be issued. While this responsibility has not yet been tested, and there is some controversy concerning the applicability of Amendments to the OCS beyond the contiguous zone, the EPA could eventually wield a high degree of control over operations on offshore structures.

The EPA, along with the departments of Interior, Transportation, and Defense, are designated the four primary Federal agencies responsible for the organization, management, design of response, and actual response to polluting incidents under the National Oil and Hazardous Substances Pollution Contingency Plan, which was incorporated into the FWPCA Amendments of 1972. The EPA is also a member of the OCS Research Management Advisory Board.

(3) Corps of Engineers, U.S. Department of the Army

The authority of the Secretary of the Army, which is delegated to the Corps of Engineers, ". . . to prevent obstruction to navigation in the navigable waters of the United States is hereby extended to artificial islands and fixed structures located on the Outer Continental Shelf," is derived from Section 4(f) of the OCS Lands Act. In general, since the Coast Guard regulates above water structures, Corps responsibility has been taken as permitting of artificial islands, structures, and pipelines. The Corps requires that pipelines crossing shipping fairways be buried to a depth of at least 10 feet. Permits for islands and structures for mineral leasing are evaluated on the bases of navigation hazards and national security.

(4) Federal Power Commission (FPC)

The FPC has discretionary powers over the approval, design and economics of common carrier gas pipelines. It also determines what the price of OCS gas will be at the wellhead. This regulated price is the base price from which the final price is determined, after costs and profit have been added. The FPC also is solicited for review and comment of draft impact statements on lease sales. The FPC issues the certificates of public convenience and necessity that are necessary for gas pipeline construction.

(5) Other Federal Agencies

(a) Fish and Wildlife Service (FWS)

The FWS (formerly the Bureau of Sport Fisheries and Wildlife) has a broad mandate to study, protect and manage fish and wildlife resources. In the offshore environment, these resources include walruses, sea otters, polar bears, sirenids, and marine birds. Onshore, FWS is concerned with fish and wildlife and their habitats and, numerous refuges under FWS jurisdiction. In the leasing program, FWS' primary role is as a reviewing agency for draft impact statements. FWS has also participated in the design of several OCS related study programs sponsored by BLM, and is a member of the OCS Research Management Advisory Board.

(b) Federal Energy Administration (FEA)

This newly created agency has broad discretionary powers over matters pertaining to energy supply and demand in the U. S. The FEA has been given the directive to implement and monitor the progress of Project Independence, among numerous other duties, and is making strides at understanding and monitoring the OCS leasing program. The FEA has recently been added to the list of agencies which are solicited for review and comment of OCS leasing impact statements.

(c) National Oceanic and Atmospheric Administration (NOAA)

The NOAA, in the Department of Commerce, has broad jurisdictional powers over many aspects of the marine environment. The number of projects and responsibilities are too numerous to list here. Historically, the prime involvement of NOAA in the OCS leasing program has been through the National Marine Fisheries Service (NMFS), which reviews impact statements and OCS permits. The NMFS has responsibility for commercial fish, migratory game fish, cetaceans and pinnipeds (other than walruses). The NOAA has a representative on the OCS Research Management Advisory Board, and is undertaking the environmental baseline studies being sponsored by BLM in the Gulf of Alaska.

(6) State Agencies - General Authorities

In general, the OCS Lands Act withdrew most control over OCS oil and gas production from coastal state jurisdiction. However, physical, chemical, geological, and biological provinces and habitats overlap Federal - State boundaries, and thus the coastal states have an interest in offshore activities that might affect their coastal resources. In addition, there are obvious economic benefits and disbenefits to a coastal state as a result of offshore development in the forms of construction equipment, refinery employment if refineries are in existence or proposed, and host of related services, secondary employments and income to the state.

There have been excellent working relationships for many years between the Federal Government and the states of Louisiana and Texas regarding offshore development. Various aspects of the program will necessitate interfacing of Federal and State governments, such as: continued review by States of proposals and environmental impact statements, relationship of OCS development to States' land use planning under the Coastal Zone Management Act of 1972, and joint participation in research projects such as pipeline corridor studies and baseline environmental inventories.

3. Related Management and Supervisory Authorities

a. Coastal Zone Management Act

The Coastal Zone Management Act of 1972 (P.L. 92-583, 92nd Congress) established Federal policy by authorizing Federal assistance to States for developing programs of coastal zone land use control and providing for States approval of Federal projects in the coastal zone. This puts authority in States' control for any coastal zone development related to offshore oil and gas exploration and transportation. The Act is environmental in orientation and is aimed at balancing the protection of the coastal zone with economic interests. Several states have applied for and received funding to develop their land use plans; the States of Washington and Maine have recently completed their draft land management plans and they have been the subjects of environmental impact statements.

b. Federal Water Pollution Control Act (1972 Amendments)

The provisions of this Act have been stated in the previous section on enforcement and contingency plans. In general, FWPCA as amended in 1972 gives the EPA broad discretionary powers in setting and enforcing standards and levels of water pollution (both fresh and marine water) from all sources. Section 311(b)(3) prohibits ". . . the discharge of oil or hazardous substances into or upon the navigable waters . . . adjoining shorelines, or into or upon the waters of the contiguous zone in harmful quantities." This section also provides for the National Contingency Plan mentioned previously. Under this authority, the EPA issued standards and measures for oil pollution prevention effective January 10, 1974 (Federal Register, December 11, 1973), proposed petroleum effluent limitation guidelines and new source standards (Federal Register, December 14, 1973), proposed designation of hazardous substances (Federal Register, August 22, 1974), and proposed regulations for water quality and pollutant source monitoring.

c. Land and Water Conservation Fund Act

The Land and Water Conservation Act of 1965 was signed into law by President Johnson on September 3, 1964. While this legislation is not related to management or supervision of OCS oil and gas, it is related to and dependent upon monies generated by lease sales and production royalties. It created outdoor recreation "accounts" for all 50 States, Puerto Rico, Virgin Islands, Guam, American Samoa, and the District of Columbia. More than $1 billion in Federal funds, derived primarily from offshore oil royalties, has gone to the 55 jurisdictions noted above, and $600 million has gone to the principal Federal land managing agencies -- Bureau of Land Management, National Park Service, Fish and Wildlife Service, and the Forest Service -- for the acquisition of lands authorized by Congress for Federal management.

The Fund was viewed as seed money for creation of recreation areas and facilities which the States, rather than the Federal Government, would manage. Other than overseeing compliance requirements, Federal officials have no role in the management of any of the State recreation areas acquired or developed with the billion dollars of Fund money.

The Bureau of Outdoor Recreation, designated by the Secretary of the Interior as manager of the Fund, makes about 2200 grants each year, ranging from a few thousand to several million dollars.

d. Endangered Species Conservation Act

The Endangered Species Conservation Act of 1969 (16 U.S.C. 688aa) requires the Secretaries of Interior and Commerce to publish in the Federal Register and periodically to modify two lists of species or subspecies of vertebrates, mollusks, or crustaceans he has determined to be either threatened with extinction within the territory of the United States or threatened with worldwide extinction. The occurrence of endangered animals in areas, either onshore or offshore, which might be affected by OCS oil and gas development is noted in environmental impact statements on such development, and is an important consideration in the decision-making for OCS lease sales. In 1973, the Fish and Wildlife Service (then Bureau of Sport Fisheries and Wildlife) published Threatened Wildlife of the United States (vertebrates only), a source document for the determination of endangered species, which can only be designated in the Federal Register.

The responsibility for the management and protection of most wildlife in the U. S. lies with the various State Conservation agencies rather than the Federal Government. An animal receives no additional Federal protection as a result of having been placed on the "List of Endangered Native Fish and Wildlife."

On December 28, 1973, Congress passed the "Endangered Species Act of 1973." This Act calls for determination of endangered species on a worldwide (rather than just U.S.) basis, authorizes land acquisition for protection of endangered species, authorizes the Secretary of the Interior to enter into cooperative agreements with States, other Nations, and other agencies for the protection and management of said species, establishes prohibited acts and the penalties and enforcement procedures necessary for protection.

e. Proposed Land Use Policy and Planning Assistance

Prior to the enactment of the Coastal Zone Management Act in 1972, at least 15 coastal states had already passed some form of coastal management legislation. The following list (Zwicky and Clark, 1973) indicates these States and includes a reference to this legislation and its year of enactment.

California: Coastal Zone Conservation Act (Proposition 20: 1972)

Connecticut: Wetlands Protection Act (Act 695: 1969)

Delaware: Coastal Zone Act (Act 175: 1971); Wetlands Act
(Sen. Bill 217: 1973)

Georgia: Coastal Marshlands Protection Act of 1970 (Act 1332: 1970)

Maine: Coastal Wetlands Act (Act 541: 1971); Mandatory Zoning and
Subdivision Control (Chapter 535: 1971)

Maryland: Wetlands Act (Act 241: 1970)

Massachusetts: Coastal Wetlands Act (Act 768: 1965)

Mississippi: Coastal Wetlands Protection Act (House Bill 140: 1973)

New Hampshire: Dredge and Fill Act (Act 215: 1967)

New Jersey: Wetlands Act (Act 272: 1970); Coastal Area Facility
Review Act (Assem. Bill No. 1429: 1973)

New York: Tidal Wetlands Act (Chapter 790: 1973)

North Carolina: Dredge and Fill Law/Coastal Wetlands Act (Act 1159: 1971)

Rhode Island: Coastal Wetlands Act (Act 140: 1965); Coastal Resources
Management Council Act (Act 279: 1971)

Virginia: Wetlands Act (Chapter 711: 1972)

Washington: Shoreline Management Act (Act 286: 1971)

The three most common reasons for such legislation were: 1) to protect wildlife and fisheries; 2) to preserve and protect ecosystems, living resources, the natural environment, or lands; and 3) to control development or growth, regulate use of land and/or reduce the burden on municipal services (Zwicky and Clark, 1973)

With the passage of the Coastal Zone Management Act in 1972, the Federal Government made a major step toward aiding coastal states in the development of cogent land use planning for the coastal zone. Funds were made available to applicant States for the drafting of land use plans, or for further definition and implementation of acceptable existing land use legislation. Numerous states have applied for such funding. The lead agency for carrying out the provisions of CZMA is the Department of Commerce, through NOAA's Office of Coastal Zone Management. Other agencies are also involved with this program. Land use policy is also involved in several specific projects requiring cooperative efforts between States and the Federal Government, such as proposed pipeline corridor studies conducted by affected States and BLM-USGS.

4. OCS Research Management Advisory Board

On March 20, 1974, the Secretary of the Interior established the Outer Continental Shelf Research Management Advisory Board under the provisions of the Federal Advisory Committee Act. The objective of the Board is to advise the Assistant Secretary - Land and Water Resources, the Director of the Bureau of Land Management, and other offices of the Department, in the design and implementation of environmental research projects related to oil and gas exploration and development on the OCS. The formally instituted Board is an outgrowth of an interagency ad hoc committee that began meeting in January, 1974 for the purpose of designing the baseline study to be conducted on the Mississippi, Alabama, Florida (MAFLA) OCS.

As the scope of future baseline and monitoring studies was expanded and a commitment of funds were made to the Department from the Office of Management and Budget, the need for a chartered Board became apparent. The establishment, functions, and charter of the Board are attached to this statement as Appendix

In general, the charter calls for the Assistant Secretary - Land and Water Resources to appoint a Department of Interior employee as chairman of the Board, after consulting with the Assistant Secretary - Energy and Minerals, and the Assistant Secretary - Fish, Wildlife, and Parks.

Each of the following Government agencies shall appoint one member: Geological Survey, Fish and Wildlife Service, Environmental Protection Agency, and National Oceanic and Atmospheric Administration. In addition, provisions are made for one member to join the Board from each coastal State. An annual report of the status of ongoing research shall be provided to the Secretary. A Chief Scientist for this program from BLM will attend all Board meetings, or send a representative.

It is intended that the members of the Board be scientists, or administrators who are familiar with ocean research and the design of large-scale environmental studies. These studies, primarily the monitoring aspect, are expected to continue for approximately ten years. Funding for the remainder of FY 74 was $1.3 million (primarily MAFLA baseline work), and the budget appropriation for FY 75 was $9.7 million. Most of this appropriation was devoted to baseline work in the Gulf of Alaska and South Texas, as well as monitoring work in the MAFLA area and other special studies.

5. Environmental Data Gathering Programs

a. Inventories and Analyses of Existing Environmental and Socio-Economic Data

The following discussion is a compilation of studies, completed, in progress, and planned, designed to acquire existing environmental and socio-economic data that relate directly or indirectly to the exploration, development, production, transportation, and refining of OCS derived oil and gas. These studies have been or will be funded by various sources, and will complement the newly acquired baseline and monitoring information to allow analyses of the impacts of the OCS oil and gas leasing program.

(1) CEQ Report

The Council on Environmental Quality was directed by the President in April, 1973 to conduct an environmental impact assessment of oil and gas production on the continental shelves of the Atlantic coasts and the Gulf of Alaska. The CEQ report was released in April, 1974 after several public hearings were held, results of contract studies were available, and a critique of the draft report was performed by the National Academy of Sciences.

The CEQ report, OCS Oil and Gas - An Environmental Assessment, addresses the following topics in detail: oil and gas resources, energy growth (demand and supply), resource development technologies and an assessment of them, offshore and onshore effects of development, and management mechanisms for OCS development. The summary of findings ranks several prospective areas on the basis of hydrocarbon potential and environmental considerations. The highest environmental risk of development was assigned to the Gulf of Alaska, then Northern Baltimore Canyon, then Southeast Georgia Embayment. These risks were based mainly on probabilities of oil spills reaching shore in these areas; these probabilities were determined using an oil spill trajectory model developed for CEQ by the Massachusetts Institute of Technology.

The conclusion of the CEQ report is that OCS development could be conducted in the Atlantic and Gulf of Alaska, but only if CEQ recommendations and stipulations are accepted. One point was clear. There are large gaps in the scientific information that cause problems in analyzing and predicting the impacts of OCS oil and gas development. Environmental baseline and monitoring studies appear necessary in these areas; the baseline aspect should be begun as soon as possible in these (and other) frontier areas. Further discussion of the CEQ report is found in Section III on Impacts.

(2) Project Independence Blueprint

Project Independence was initiated in March, 1974 to evaluate the Nation's energy problems and provide a framework for developing a national energy policy. The Federal Energy Administration directed a large multi-energy effort on these objectives and produced a final report in November, 1974. Some of the major findings of the report are listed below.

1. The world oil price will largely determine U.S. energy prices and, in turn, affect both U.S. supply possibilities and rate of energy growth.

2. At $11 world oil prices, domestic energy demand will grow at substantially lower rates than it has in the past (approx. 2.7% per year).

3. Petroleum production is severely constrained in the short run and greatly affected by world oil prices in the long run.

4. Coal production will increase significant, but is limited by lack of markets.

5. Potential increases in natural gas production are limited, but continued regulation could result in significant declines.

6. Synthetic fuels will not play a major role between now and 1985; geothermal, solar, and other advanced technologies are large potential sources, but will not contribute to our energy requirements until after 1985.

7. Oil imports will remain level or rise in the next few years, no matter what long-term actions we take.

8. Energy production through 1985 will have mixed environmental impacts.

9. Federal policies to lease the Atlantic OCS, reopen the Pacific OCS and tap the Naval Petroleum Reserves can dramatically increase domestic oil production.

10. Energy conservation actions can reduce demand growth to about 2.0 percent per year between 1972 and 1985.

Along with these and other findings, the FEA lists major uncertainties with attaining independence from foreign energy supplies, as well as the policy implications of such a shift. Major energy sources (such as OCS oil and gas) are addressed in detail as to their potential production, impacts of production, and relation to the total energy supply mix in 1985, under various pricing levels.

(3) Department of Interior Contracts

As an integral part of its OCS leasing program, the Bureau of Land Management has undertaken a broad-based inhouse and outside contract study effort to aid in the design, modification, and implementation of the leasing program. Besides the large-scale baseline and monitoring studies discussed later, the Bureau has awarded several contract studies for the purpose of gathering and consolidating available environmental and socio-economic data in several geographic areas. The topics of primary interest in environmental studies are: (1) coastal zone--climate, ecology, physical properties, man-made features, and hydrography, and (2) continental shelf--physical oceanography, meteorology, geology and marine ecology.

The socio-economic studies will review industrial and commercial activity, petroleum industry development, demography, land and water use, sources of pollution, and existing transportation systems.

(a) Atlantic Area

The Bureau of Land Management funded the study, A Socio-Economic and Environmental Inventory of the North Atlantic Region. This study was conducted by the Research Institute of the Gulf of Maine (TRIGOM). The draft report constitutes a substantial effort to collect and summarize all available environmental and socio-economic information (no original research) pertaining to the Atlantic coastline from Sandy Hook, New Jersey, to the Bay of Fundy. This report was completed in March, 1975.

A contract for the gathering of socio-economic data pertaining to mineral leasing on the OCS from Sandy Hook, New Jersey to Cape Hatteras, North Carolina, was awarded to the College of Marine Studies, University of Delaware.

The CEQ, through a transfer of funds from BLM, issued a contract to study to evaluate environmental and socio-economic conditions from Cape Hatteras to Cape Canaveral, Florida. This study is completed, is similar to the TRIGOM study above, and was conducted by the Virginia Institute of Marine Science.

The Bureau of Land Management is presently funding a long-term study of the fate and effects of No. 6 oil (a heavy fuel oil) in a high temperate estuary (Casco Bay, Maine). This research effort is being conducted by the Bureau of Marine Resources of the State of Maine. Investigations include weathering, oil residence time in sediments, biological concentrations within the clam *Mya arenaria*, and the chronic effects of oiling on *Mya*.

(b) Gulf of Mexico

A study of the Gulf of Mexico was awarded to Environmental Consultants of Dallas, Texas. The contract called for an updating and broadening of the Cooperative Investigation of the Caribbean and Adjacent Regions (CICAR) Bibliography that was published in 1972 by the U.S. Department of Commerce's National Oceanic and Atmospheric Administration. The contract also provides for identification of research in progress relating to CICAR categories and a socio-economic study of the Gulf of Mexico. Another contract was recently issued by BLM to TerEco Corporation of College Station, Texas entitled "Ecological Aspects of the Upper Continental Slope, Gulf of Mexico". The study is an analysis of organisms and sediments that have already been collected from the continental slope from DeSoto Canyon off Louisiana to the Mexico-U.S. border. Organisms will be identified, population sizes and distributions determined, and correlations of organism occurrences will be made with sediment type analyses, temperature-salinity characteristics, and depth. This study is scheduled for completion in June, 1975.

An investigative effort has been proposed to conduct a submersible reconnaissance of 14 to 18 topographic highs on the Texas OCS. The reconnaissance would allow visual (operators' reports, videotape, still photographs) characterization of these sites as potentially valuable resources (commercial fish havens, reefs or reef-type communities). Biological and geological sampling will also be conducted. This effort will be conducted as a complement to the environmental baseline studies in the South Texas area.

The baseline studies in the South Texas area, as well as their forerunner in the eastern Gulf (MAFLA) area, are discussed in a later section.

An inhouse study in cooperation with the States of Mississippi, Alabama, and Florida has been initiated to conduct a pipeline corridor analysis of the northeastern Gulf of Mexico. This study will analyze for siutable physical, geological and onshore developmental areas for corridors.

(c) Southern California

A study of the Southern California offshore borderland area was awarded to the Southern California Ocean Studies Consortium (SCOSC). This study, which has also been completed, includes existing environmental and socio-economic data that could relate to mineral leasing in this area.

In addition, a contract for the development of an oil transportation computer model was awarded to Stanford Research Institute of Menlo Park, California. This model will aid in the analysis of Outer Continental Shelf oil resources and alternative sources of petroleum supply to help meet future regional demands and to assess the effects of prices and transportation costs relating to regional supplies and flow patterns.

(d) Alaska

The Gulf of Alaska and adjoining OCS areas of the Pacific Ocean, Cook Inlet to Unimak Island - was awarded to The Arctic Environmental Information and Data Center of the University of Alaska at Anchorage, Alaska. The study will include environmental and socio-economic data.

(e) Potential Special Field Studies

Studies involving field or laboratory research, as opposed to existing information searches, which have been proposed but not yet fully funded or developed include the following:

1. A submersible reconnaissance mission of topographic highs on the Texas OCS to assess their resource value as possible commercial fishing havens or reef-type communities.

2. Pipeline corridor studies involving suitable OCS and onland areas in affected States.

3. An archeological resources survey of the Gulf of Mexico, including a preliminary determination of areas having a high probability of occurrence of such resources.

4. The Department of the Interior is open to suggestions from the public concerning future projects to be undertaken under the special studies program. Such suggestions should address the issue of how development might be conducted in a given area in the least environmentally damaging way. In particular, they should attempt to indicate what sort of lease stipulations the Department might consider adopting for this purpose. These suggestions need not be prepared according to any particular format. They should be sent, in two copies, to: (1) Chief, Division of Minerals Environmental Assessment, Bureau of Land Management, and (2) Assistant Secretary, Program Development and Budget. In both cases the address is Department of the Interior, 18th and C Streets, N.W., Washington, D. C. 20240.

(f) Baseline Environmental Data Gathering

(i) OCS Research Management Advisory Board

The OCS Research Management Advisory Board was established on March 20, 1974 by the Secretary of the Interior to aid in the design and implementation of the baseline and monitoring studies on the OCS. The functions of the Board were discussed previously; the charter is included as Appendix D. The precursor to the Board, an interagency ad hoc committee, began the work in January, 1974 that allowed the MAFLA baseline studies to begin.

(ii) Mississippi-Alabama-Florida OCS Baseline Study

The MAFLA baseline study was begun in April, 1974 and was conducted by the State University System Institutes of Oceanography (SISIO). It constituted on intensive short-term effort at collecting oceanographical, biological, and geological information in the MAFLA area before the scheduled exploration activities were begun. Classical oceanographic techniques were employed in the data collection period, including water collection for microbial biomass, micronutrients, low molecular weight hydrocarbons, dissolved oxygen, organic carbon (particulate and dissolved), trace metals, particulate high molecular weight hydrocarbons, temperature, salinity, and depth, and stepped oblique tows for zooplankton using ½ meter nets with

with opening/closing devices. All these samplings were done on 15 meter stations and 4 control stations. Bottom sampling was accomplished on 40 master stations and 25 control stations. This sampling included the following: box cores for infaunal macrofauna, hydrocarbon analysis, trace metal analysis, total organic carbon, and sediment analysis. Bottom photography and dredges were used for characterizing epifauna and apiflora.

Samples taken during the 60 day sampling period were then analyzed. Analysis included sorting and identification of organisms, sedimentalogical characterizations, and chemical analyses of water, sediments and organisms to determine benchmark levels of hydrocarbon and trace metal contamination. Quality control checks were also provided on these chemical analyses.

While this brief account of the program may not give a layman an idea of the scope and complexity of the sampling and analysis, it is felt that such a research effort will yield substantive information which will provide an adequate baseline against which future changes due to oil and gas operations can be compared. The draft final report on this phase of the program was submitted to BLM in March, 1975.

(iii) Proposed Gulf of Alaska Baseline Data Gathering

Baseline data collection begain in the Gulf of Alaska in September, 1974 and is continuing. An interagency Agreement was signed between BLM and the National Oceanic and Atmospheric Administration (NOAA) which assigns NOAA as program manager for the entire research program in Alaska. The BLM retains the program overview function mandated by its funding pass-through role and design coordination role in all OCS areas. Other Federal agencies, such as USGS and F&WS, as well as State of Alaska agencies and academic institutions, are also involved in carrying out the sampling and analysis of data for the Gulf of Alaska program.

(iv) South Texas Baseline Study

The South Texas baseline study was initiated in the fall of 1974 with an extensive biological and geological sampling effort. The program is coordinated by the USGS in Corpus Christi through a memorandum of understanding with BLM; additional elements include an interagency agreement with the National Ocean Survey of NOAA for certain historical information, and a contract with the University of Texas for major portions of the biological and chemical sampling and analysis. Geologic sampling has been completed and the second of three seasonal biological sampling elements was recently completed.

(v) Other Potential Data Gathering Programs

Environmental baseline studies similar to the MAFLA and Gulf of Alaska programs are planned for initiation in calendar year 1975 in the Southern California area, and in the middle Atlantic area. The studies in these areas are still in the preliminary stages; actual research has not yet begun. The FY 75 budget request for these sampling and analysis programs was $9.7 million.

(g) Environmental Monitoring Programs

Environmental monitoring programs are the natural follow-up programs to the environmental baseline programs. Utilizing similar sampling and analytical techniques, and previously identified sampling sites, additional collections of organisms, sediments, and water will be accomplished after exploration (and possibly production) have begun. After analysis and data reduction, a comparison of the environmental parameters measured can be made, and an estimate of the correlation between the observed changes and the degree and proximity of oil and gas development can also be made. Monitoring studies in all geographic areas that have baseline studies will continue for several years after the onset of development, in order that the longer range impacts may be quantified. At the present time, no monitoring programs have been designated, and no contracts awarded or memoranda of understanding between agencies formulated. Preliminary planning by the Research Management Advisory Board has begun, however.

In conjunction with the MAFLA baseline study, a contract was awarded to SUSIO, University of Alabama, University of Miami, Texas A&M University and NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) in Miami to compile, summarize, and present all existing hydrographic data for the eastern Gulf of Mexico. Data includes what is available from National Data Centers, published literature, unpublished research results, and personal files. This study will provide the best available analysis of the circulation patterns in the deep water of the Eastern Gulf and the continental shelf, and will show the relationship between the two. Availability of the data will enable the Bureau to plan future sampling effort in such a way as to maximize the quality of data being returned. A separate contract is being negotiated to construct a hydrographic model of Eastern Gulf of Mexico circulation. Concurrently, the monitoring component of the environmental studies effort in the area has been designed, and a contract will soon be issued to SUSIO, pending negotiations concerning the actual work to be accomplished. The monitoring phase is functionally defined as those studies that begin after drilling operations have begun. However, although operations have begun in the MAFLA area, no production has begun; thus, much of the monitoring will actually gather more information that can be added to the benchmark data base.

(4) Other Applicable Studies

There have been several studies recently completed which identify weaknesses in OCS operating regulations and procedures and recommend remedial measures. The Geological Survey had undertaken on their behalf studies conducted by NASA 1/, the Marine Board of the National Academy of Engineering 2/, and an internal System Laboratory Group of the Water Resources Division of the Geological Survey 3/. An analysis of the results of these studies was completed by a special Work Group of the GS in May, 1973, and a report titled the "Work Group on OCS Safety and Pollution Control" was issued. Implementation has commenced on all 15 recommendations made by the Work Group in its report.

In addition to the above studies and reports, the General Accounting Office (1973) issued a report at the request of the Conservation and Natural Resources Subcommittee of the Committee on Government Operations, House of Representatives. This study, like those mentioned above, presents a critical review of OCS regulatory and inspection procedures and includes recommendations designed to

---

1/ NASA, "Applicability of NASA Contract Quality Management and Failure Mode Effect Analysis Procedures to the USGS Outer Continental Shelf Oil and Gas Lease Management Program", November, 1971.

2/ Marine Board, National Academy of Engineering, "Outer Continental Shelf Resource Development Safety: A Review of Technology and Regulation for the Systematic Minimization of Environmental Intrusion from Petroleum Products", December, 1972.

3/ USGS, "Outer Continental Shelf Lease Management Study", May, 1972.

achieve more effective capability and procedures. In a letter dated August 3, 1973, from Secretary Morton to Mr. Henry S. Reuss, Chairman of the Conservation and Natural Resources Subcommittee, it is pointed out that the recommendations contained in the GAO report which have not already been implemented are being implemented as part of the Work Group's recommendations. Many of the recommendations contained in the GAO report were also made in the studies discussed above. A comprehensive report of a technology assessment of oil and gas operations on the U.S. Outer Continental Shelf was published by an interdisciplinary research team from the Science and Public Policy Program at the University of Oklahoma (Kash, et al., 1973). The independent analysis, funded by the National Science Foundation, was conducted over a 20 month period beginning in September, 1971.

The principle conclusions of the study are: (1) that existing OCS technologies are adequate for continued oil and gas operations; (2) that more sharply defined concerns for safety and environmental protection continue to pose a challenge to OCS management even though technologies responsive to these new concerns are gradually evolving; (3) that in the past, participation in the management of OCS oil and gas operations was limited to the Department of the Interior and the petroleum industry and that this relatively closed management system was initially unable to sense and respond quickly to a changing social climate. Interested groups and Federal agencies representing concerns such as environmental conservation are now participating in the management system primarily through the impact statement process required by NEPA. These new participants are demanding changes from past patterns of operations; and (4) most of the new demands being made on OCS technologies are well within state-of-the-art. The necessary information modifications in the physical technologies required by a changing social climate can be met. Although the application of stringent environmental and safety criteria pose problems, the industry either has or can develop the required physical technologies and procedures. The Work Group of the GS in May 1974 issued 'Supplement No. 1 to the Report of the Work Group on OCS Safety and Pollution Control, May 1973." (Supplement No. 2 has now been issued).

> "This report considers the recommendations of the Oklahoma University study which were directed to the Geological Survey as a result offers revision to previous recommendation nos. 4, 9, and 13, and adds four additional recommendations. The Director of the Geological Survey has accepted these recommendations and implementation has commenced."

The American Petroleum Institute funded a study conducted by the University of Rhode Island which was published in 1974. This study attempted to review all significant literature pertaining to environmental and socio-economic conditions along the Atlantic coastline from Cape Hatteras to Sandy Hook, New Jersey.

6. Requirements for OCS Facilities and Equipment

a. Recent Studies of OCS Technology and Practices

The term OCS Technology and Practices covers such a broad spectrum of individual technologies and practices that it is virtually impossible to maintain an up-to-date published study of "OCS Technology". The 378 page volume Energy Under the Oceans - A Technology Assessment of Outer Continental Shelf Oil and Gas Operations published in 1973 by the University of Oklahoma Press is one reference used extensively throughout this statement. Attachment E of this statement is the GS comments on the recommendations made in this "Energy Under the Oceans" and comments also on recommendations made in three other reports identified in the appendix to the GS report. Preceeding all of these was the Report to the Conservation and Natural Resources Subcommittee, of the Committee on Government Operations House of Representatives entitled "Improved Inspection and Regulation Could Reduce the Possibility of Oil Spills on the Outer Continental Shelf" by the Comptroller General of the United States. Each year the Offshore Technology Conference (OTC) publishes the papers submitted to the conference--in 1974 there were 183 technical reports published by the OTC. In addition, there are several commercial publications reporting on worldwide offshore technology at regular intervals.

b. Requirements for Evaluation and Approval of Designs for OCS Facilities and Equipment

The OCS operator must obtain a permit before commencing various steps in the operating plan. Permits are granted by one or more of the following agencies: U.S. Geological Survey; Bureau of Land Management; U.S. Coast Guard; Office of Pipeline Safety; Environmental Protection Agency; Corps of Engineers, United States Army; Interstate Commerce Commission. The major controlling agency for operations is the U.S. Geological Survey (GS) who issues permits for drilling and workover operations and platform installations including production facilities. They also monitor pipeline operations. The Bureau of Land Management issues right-of-way permits for common carrier pipelines and GS approves lease gathering lines. GS in both the Gulf of Mexico and Pacific OCS has issued a series of Operating Orders which are revised from time to time as required. The GS permits and OCS orders, in general, will provide the requirements for evaluation and approval of designs for OCS facilities and equipment.

c. Establishment of Performance Standards for OCS Facilities and Equipment

This, generally, is the same as the preceeding paragraph. The OCS Orders issued by GS will stipulate certain minimum testing requirements as well as the form and frequency of reporting both routine tests plus failures as they occur or are detected.

II. DESCRIPTION OF THE ENVIRONMENT

A. Description of the Offshore Environment

1. Atlantic Region

a. Geology

The Atlantic Continental Shelf represents a natural seaward extension of the onshore Atlantic Coastal Plain, a gently-sloping cover of Mesozoic [1] and Cenozoic sedimentary strata stretching over an area of more than 100,000 square miles from southern New England to southern Florida. Offshore, the continental shelf, slope and rise comprise the Atlantic continental margin of North America. Uchupi (1970) divided this offshore region into a northern physiographic segment extending from Nova Scotia southward to Cape Hatteras, North Carolina and a southern segment between Cape Hatteras and the Florida Keys. The northern segment is characterized by a 'normal' continental margin progression. The relatively-smooth, gently-dipping shelf extends seawards to a water depth of 100 to 200 meters; a break at this depth marks the beginning of the more steeply-inclined continental slope. At the foot of the slope, regional declivity decreases onto the continental rise which slowly descends from a water depth of 2000-3000 meters to oceanic basin depths exceeding 5000 meters.

The southern segment of the east coast continental margin differs from that to the north in possessing a sub-province, the Blake

---

[1] A geologic time chart is included for reference as Fig. 2.

FIGURE 2. GEOLOGIC TIME CHART

AGE DIVISIONS			TIME			
ERA	PERIOD	EPOCH	DURATION IN MILLIONS OF YEARS ERA	PERIOD	EPOCH	BEGINNING MILLIONS OF YEARS AGO
CENOZOIC	QUATERNARY	RECENT	63	1.011	0.011	0.011
		PLEISTOCENE			1	1
	TERTIARY	PLIOCENE		62	12	13
		MIOCENE			12	25
		OLIGOCENE			11	36
		EOCENE			22	58
		PALEOCENE			5	63
MESOZOIC	CRETACEOUS		167	72		135
	JURASSIC			46		181
	TRIASSIC			49		230
PALEOZOIC	PERMIAN		370	50		280
	PENNSYLVANIAN			40		320
	MISSISSIPPIAN			25		345
	DEVONIAN			60		405
	SILURIAN			20		425
	ORDOVICIAN			75		500
	CAMBRIAN			100		600
PRE-CAMBRIAN	GRENVILLE OROGENY		4000			1000
	OLDEST KNOWN ROCKS IN NORTH AMERICA					3200
	OLDEST KNOWN ROCKS (MURMANSK AREA)					3400
	PROBABLE AGE OF THE EARTH					4600

Plateau, which intervenes between the continental shelf and slope. The continental rise is essentially missing from this southern sequence.

Structure

In general terms, seismic profiling data reveal variations in the velocity of sound energy transmission through rock strata. Since many physical properties of rocks (e.g. mineralogic and textural composition, porosity, fluid content, degree of compaction and alteration) interact to produce a particular velocity profile, the interpretation of seismic data, without confirmative drilling information, is frequently difficult. Seismic data will, however, generally reveal a 'basement' layer or sub-bottom surface that strongly reflects seismic energy and that is construed to have once been a regional depositional surface now overlain, commonly to great thicknesses, by sedimentary rock strata. The terms 'effective basement' and 'economic basement' refer to the subsurface layer below which there is no current exploration interest. With changing economic conditions and improved technology, deeper rocks may become prospective for oil and gas, and the 'economic basement' redefined.

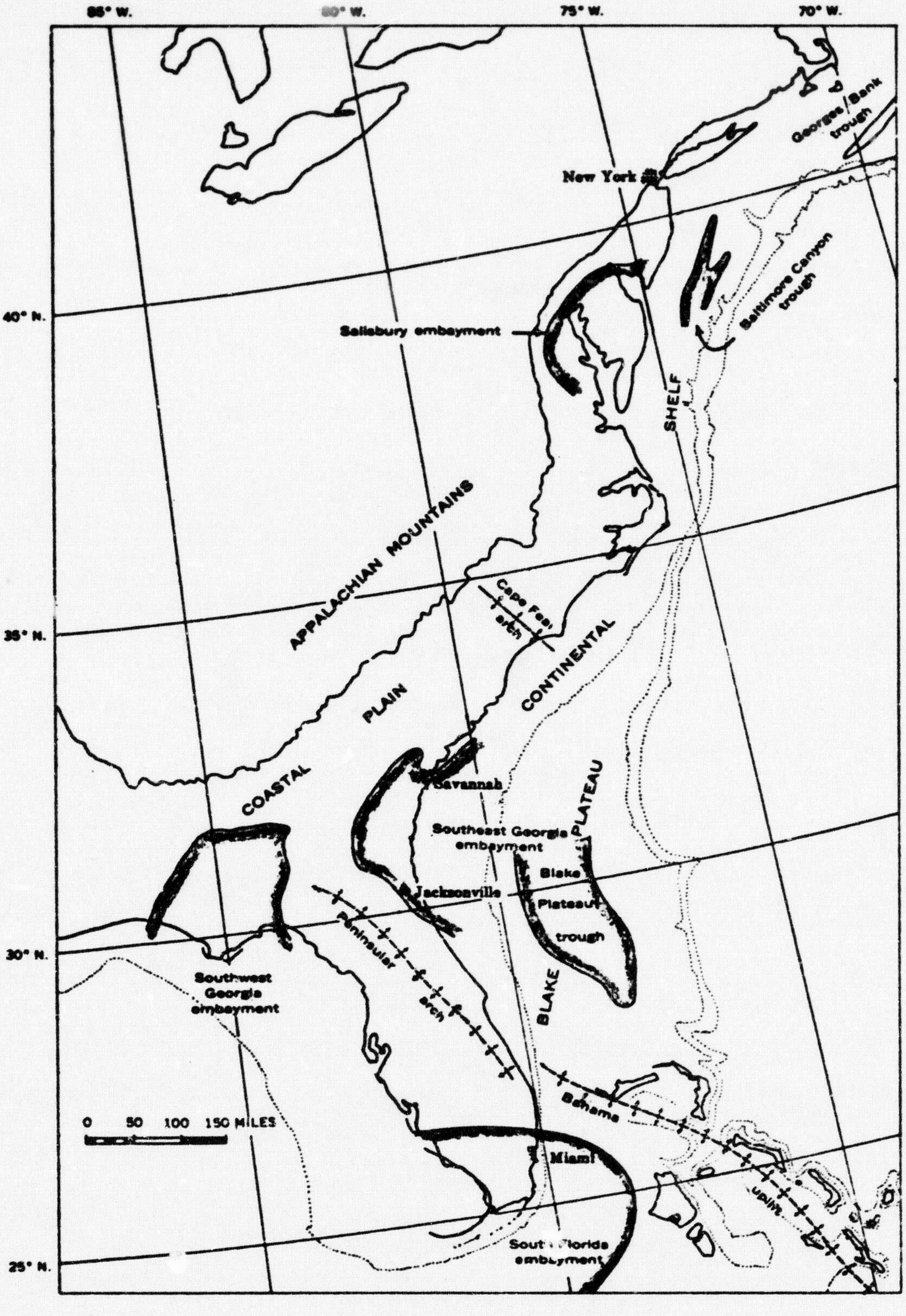
While mapping the configuration of the basement surface can be highly interpretive, the delineation of this datum or reference surface allow more meaningful structural interpretation and subsequent evaluation of subsurface resource potential.

Beneath the Atlantic coastal plain and continental shelf, the pre-Jurassic basement surface slopes increasingly seaward, with structural contours broadly paralleling the Appalachian Mountain System. Towards the coast and offshore, this trend is interrupted by several prominent structural features: the positive Cape Fear and Peninsular Arches and the negative Salisbury and Southeast Georgia Embayments. Figure 3 shows these and other major structural elements of the western Atlantic margin.

The seaward-thickening wedge of Mesozoic and Tertiary strata off the Atlantic coast fills a depositional trough beneath the shelf which is bounded on the east by a deeply-buried basement ridge (Drake, et al., 1959). This ridge extends along the outer shelf margin and separates the inner sedimentary trough from an outer, deeper trough located beneath the continental slope and rise. Regional thickenings occur along several portions of the inner depositional trough. These areas include the Baltimore Canyon, Georges Bank, and Emerald Bank (Sable Island) troughs (Maher, 1965; Maher and Applin, 1971). Basement contours beneath the Blake Plateau reveal a broad, northward-trending structural depression that is more than 6 km deep and is appropriately called the Blake Plateau trough.

Bottom Sediments

Figure 4 gives the general distribution of sediment types off the Atlantic coast, with respect to texture, contributing agent and



85° W.
80° W.
75° W.
70° W.
40° N.
35° N.
30° N.
25° N.
New York
Georges Bank trough
Baltimore Canyon trough
Salisbury embayment
SHELF
APPALACHIAN MOUNTAINS
Cape Fear arch
CONTINENTAL
PLAIN
COASTAL
Savannah
Southeast Georgia embayment
PLATEAU
Blake Plateau trough
Jacksonville
Peninsular arch
Southwest Georgia embayment
BLAKE
Bahama uplift
Miami
South Florida embayment
0 50 100 150 MILES

FIGURE 3.—Index map of Atlantic Coastal Plain and Continental Shelf showing principal structural features (modified from Maher, 1971).

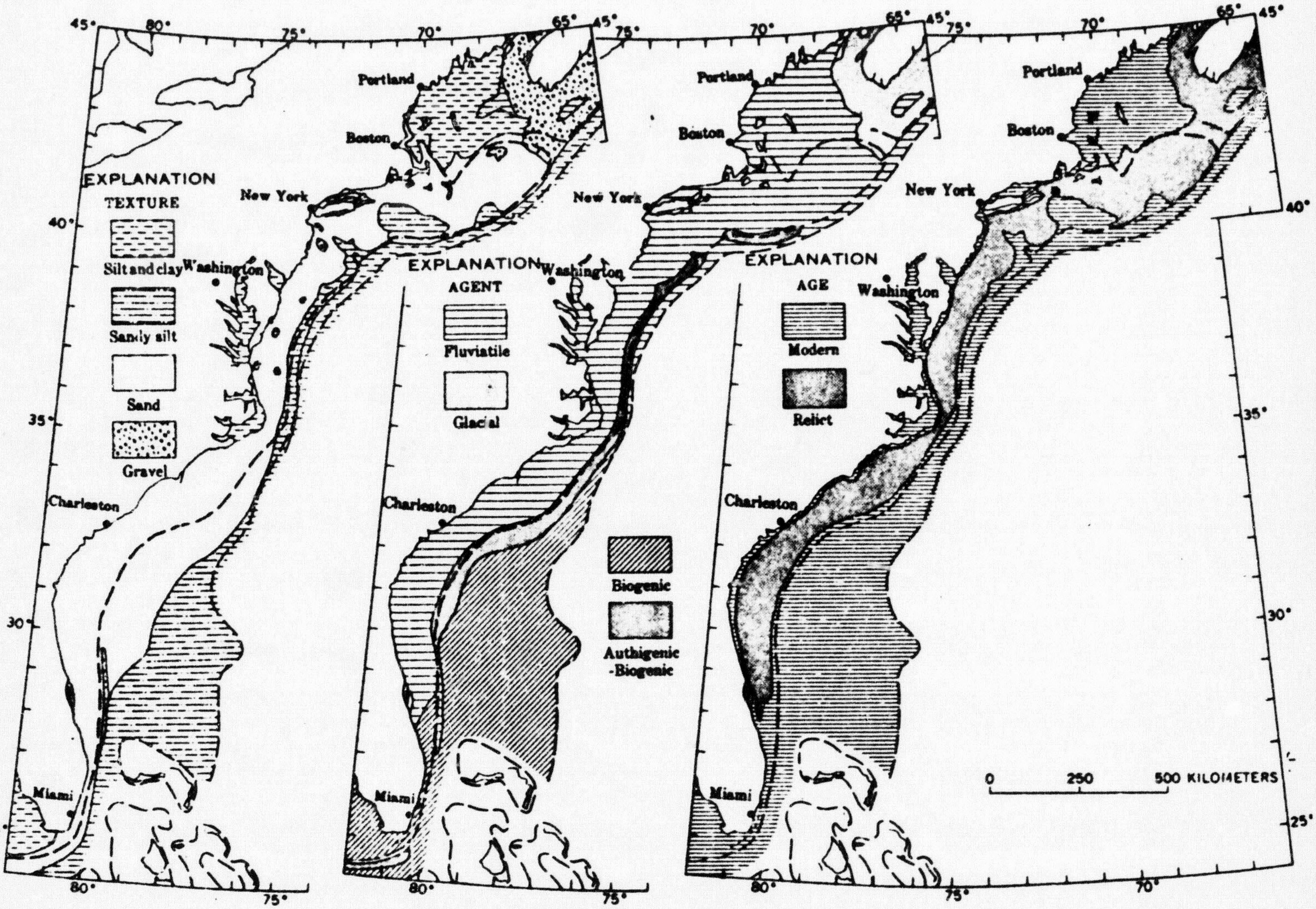

45°
80°
75°
70°
65°
40°
35°
30°
25°
Portland
Boston
New York
Washington
Charleston
Miami
EXPLANATION
TEXTURE
Silt and clay
Sandy silt
Sand
Gravel
EXPLANATION
AGENT
Fluviatile
Glacial
Biogenic
Authigenic-Biogenic
EXPLANATION
AGE
Modern
Relict
0
250
500 KILOMETERS

FIGURE 4 -Sediments off the Atlantic coast of the United States classified by texture, contributing agent, and age. The charts are based upon inspection of about 1,600 samples prior to detailed laboratory analyses. (from Emery, 1966).

age. Textural complexity is most apparent in the northeastern areas, particularly in the glaciated and ice-rafted relic sediments of the Gulf of Maine. From Georges Bank southwestward, relict sands dominate much of the shelf. Modern clastic (land-derived) sands are generally restricted, north of Cape Hatteras, to a narrow nearshore zone. South of the Cape, these deposits grade into modern biogenic (shell) sands and, over the Blake Plateau, biogenic sandy-silt. Estuarine and other protected coastal areas are dominated by modern silts and clays. These fine-grained modern sediments also mantle the continental slope.

Geologic Occurrence of Fluid Hydrocarbons

Economically-attractive accumulations of oil and/or gas owe their existence to the proper interplay of three essential geologic elements. These are: a) source beds-rock strata which supply the organic material that is eventually transformed into fluid hydrocarbon; b) reservoir beds--porous strata into which these hydrocarbons migrate; and c) a trapping mechanism--a structural or stratigraphic (compositional) barrier which interrupts further migration and allows significant hydrocarbon accmulations to develop.

Source beds for hydrocarbons are generally regarded to be marine shales, marls (clacareous clays) and carbonates, in about that order of importance. Chemical processes involved in the conversion of organic debris in these rocks to oil and gas occur at extremely slow rates, and require initial conditions of quick burial such as those found in areas of rapid sedimentation.

Potential reservoir strata, generally sandstone or limestone, must be characterized by sufficient porosity and permeability, and be located close enough to the source beds to accommodate the migration of the hydrocarbon fluids along pressure gradients.

These fluids would continue to ascend the stratigraphic rock sequence if there was not some impervious barrier present to halt this movement. The favorable structural relation of permeable rock strata with an impermeable sealing bed is known as a 'trap'.

Traps for fluid hydrocarbons are broadly classified as either stratigraphic or structural, although many have elements of both these types. Figure 5 illustrates three of the more common traps; anticlinal and fault types are structural in nature, while the stratigraphic trap is compositional.

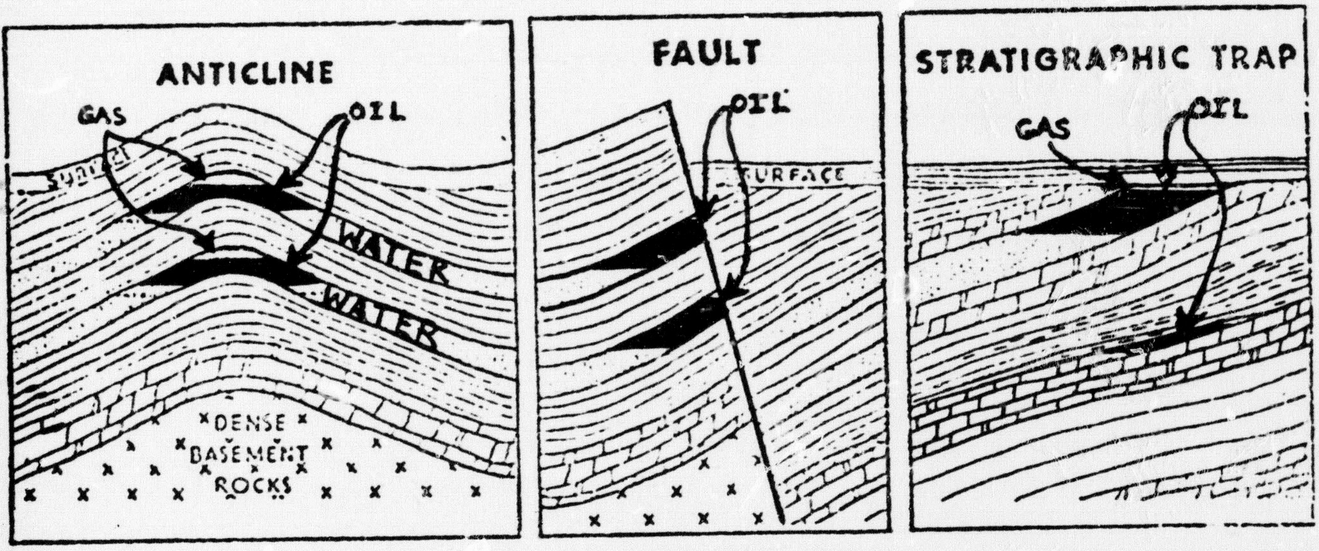

ANTICLINE
GAS
OIL
SURFACE
WATER
WATER
DENSE BASEMENT ROCKS
FAULT
OIL
SURFACE
STRATIGRAPHIC TRAP
GAS
OIL

Fig. 5. TYPES OF FLUID HYDROCARBON TRAPS

(From *Petroleum Discovery and Production*, pamphlet, American Petroleum Institute, New York, N.Y.)

Fluid hydrocarbon accumulations are density-stratified; gas, if present as a separate phase, assumes the highest position in the trap while any water present, being more dense than both oil and gas, assumes the lowest. All these fluids exist under relatively high formation pressures due to the weight of overlying material.

Hydrocarbon Potential of the Atlantic OCS

The Atlantic OCS is essentially an untested region. Although a significant body of offshore geophysical data exists, actual sampling of the bottom strata has been mainly limited to scattered dredge hauls and shallow cores; a few test holes have been drilled into shelf areas off Georgia and Florida. Much of the inferred offshore stratigraphy beneath the shelf has been interpreted from onshore drill data obtained from widely-spaced wells scattered along the Atlantic coastal plain.

In the north Atlantic, on Canada's eastern continental shelf, drilling activity has occurred since 1965, with 54 wells drilled or were being drilled by the end of 1972 (Amoco Ltd. and Imperial Oil Ltd. Staffs, 1974). Information gained from these wells has been helpful in interpreting geophysical data from the northeastern United States continental shelf.

Sedimentary rocks of the Atlantic OCS were deposited primarily in a transitional shallow-marine environment so that the present stratigraphic sequence probably contains a good mix of potential reservoir and source beds.

Favorable structures occur beneath several areas of the shelf, with many, such as those within the Georges Bank and Baltimore Canyon trough regions, representing possible structural traps. In southern areas of the Atlantic shelf and slope, hydrocarbon accumulations may occur in association with reef structures and stratigraphic traps resulting from the intermingling of carbonate, clastic and evaporite strata.

(1) North Atlantic OCS

(a) General

The North Atlantic continental shelf area includes several varied physiographic regions. The East Coast shelf, located to the south of Long Island is relatively featureless while further north, the floor of the Gulf of Maine has been severely altered by Quaternary glacial events. An anomalous extension of the East Coast shelf, Georges Bank, lies between these two physiographic regions and shares topographic characteristics with both. Several prominent submarine canyons dissect the continental slope of the North Atlantic region. Figure 6 shows the general physiography of the northeastern United States continental margin.

(b) Hydrocarbon Potential

The feature thought to have the greatest current hydrocarbon potential in the north Atlantic OCS region is the Georges Bank trough, an arcuate, northeast-southwest trending

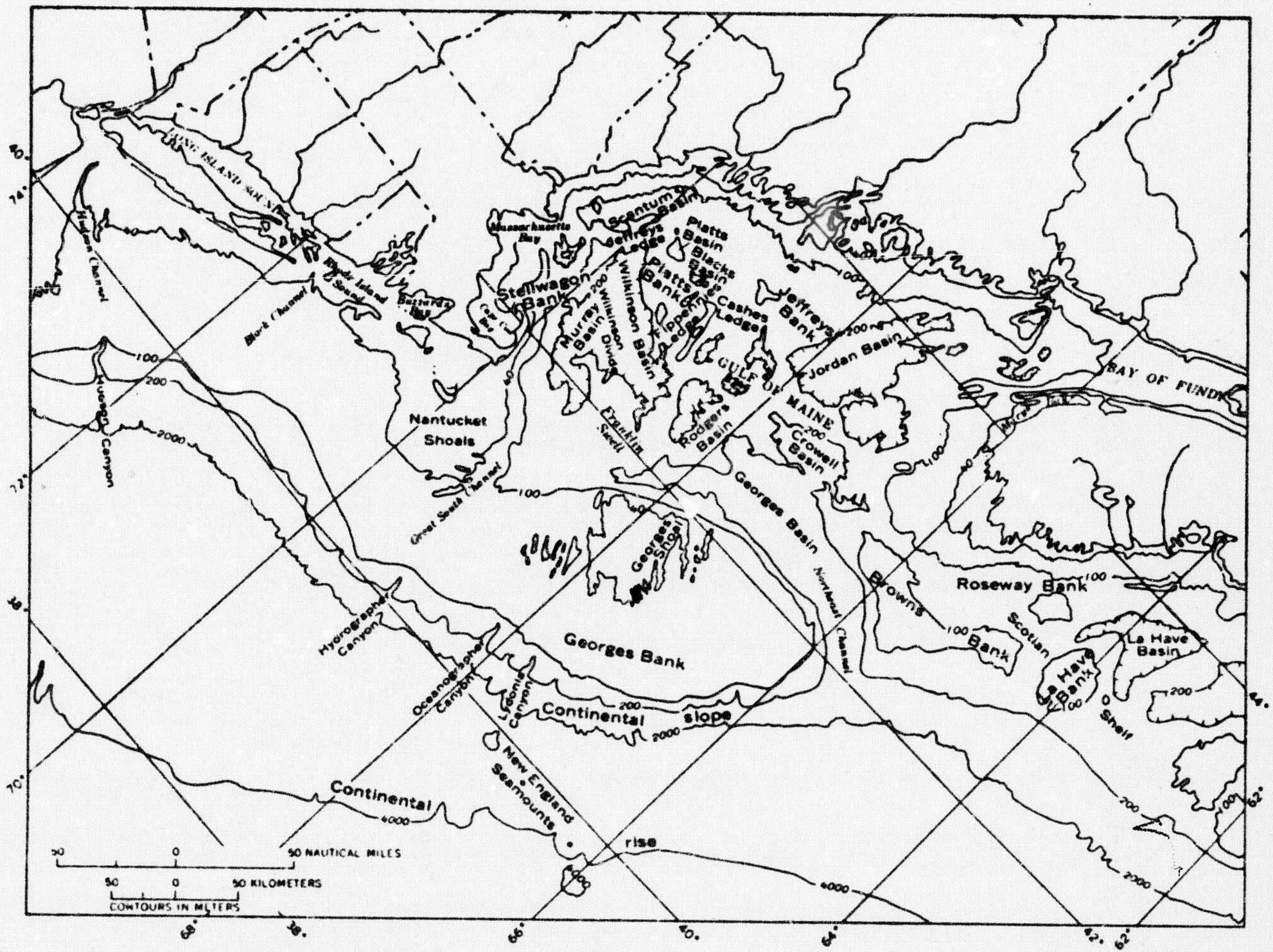

LONG ISLAND SOUND
Hudson Channel
Hudson Canyon
Block Channel
Rhode Island Sound
Buzzards Bay
Massachusetts Bay
Cape Cod Bay
Stellwagon Bank
Scantum Basin
Jeffreys Ledge
Platts Basin
Blacks Basin
Platts Bank
Murray Basin
Wilkinson Divide
Wilkinson Basin
Fippennies Ledge
Cashes Ledge
Jeffreys Bank
Jordan Basin
GULF OF MAINE
Rodgers Basin
Crowell Basin
Franklin Swell
Nantucket Shoals
Great South Channel
Georges Shoal
Georges Basin
Northeast Channel
Georges Bank
Browns Bank
Roseway Bank
Scotian Shelf
La Have Bank
La Have Basin
BAY OF FUNDY
Hydrographer Canyon
Oceanographer Canyon
Lydonia Canyon
Continental slope
Continental rise
New England Seamounts
100
200
2000
4000
40°
42°
44°
74°
72°
70°
68°
66°
64°
62°
50
0
50 NAUTICAL MILES
50
0
50 KILOMETERS
CONTOURS IN METERS

FIGURE 6.-Bathymetric map of the continental margin off the Northeastern United States. (from Schlee, 1973; after Uchupi, 1965).

structural depression on the basement surface beneath Georges Bank. The trough is approximately 120 miles (193 km) long and up to 8 km in depth. Figure 7 gives the general location and configuration (in depth to basement) of this structural feature.

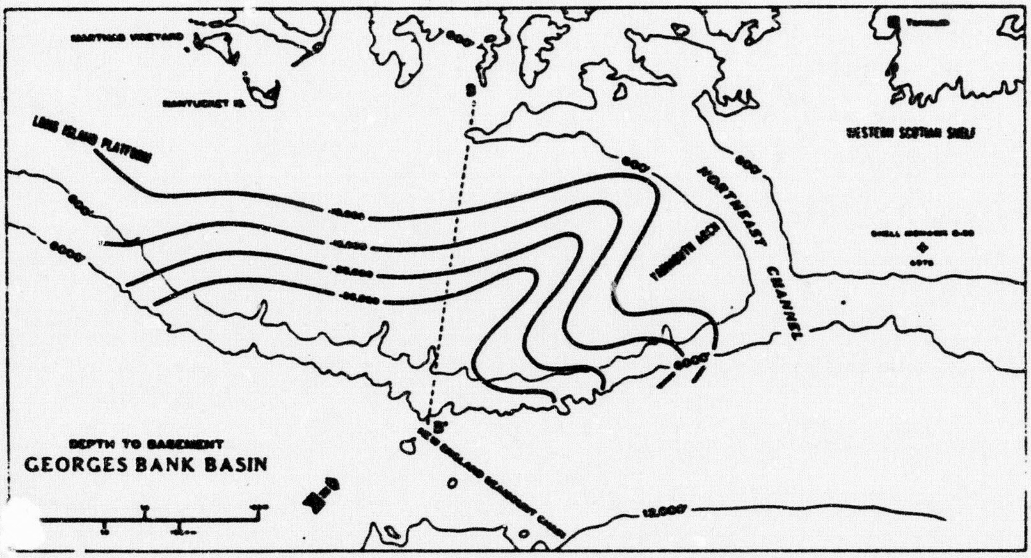

MARTHAS VINEYARD
NANTUCKET IS.
LONG ISLAND PLATFORM
600'
6000'
B
B'
WESTERN SCOTIAN SHELF
NORTHEAST CHANNEL
YARMOUTH ARCH
12,000'
NEW ENGLAND SEAMOUNT CHAIN
DEPTH TO BASEMENT
GEORGES BANK BASIN

FIG. 7 -Generalized structure-contour map showing depth to pre-Mesozoic basement. Contour interval 5,000 ft. Based on Maher (1965) and other published data.
(from Schultz and Grover, 1974).

Seismic data and information from wells drilled into the adjacent western Scotian shelf suggest the presence of up to 14,000 feet of Lower Cretaceous and earlier Mesozoic carbonate, marine shale, evaporites and sandstone overlain by as much as 12,000 feet of Upper Cretaceous and Tertiary sandstone and shale (Schultz and Grover, 1974). A generalized northwest-southeast cross-section through the Georges Bank trough is shown in Fig. 8.

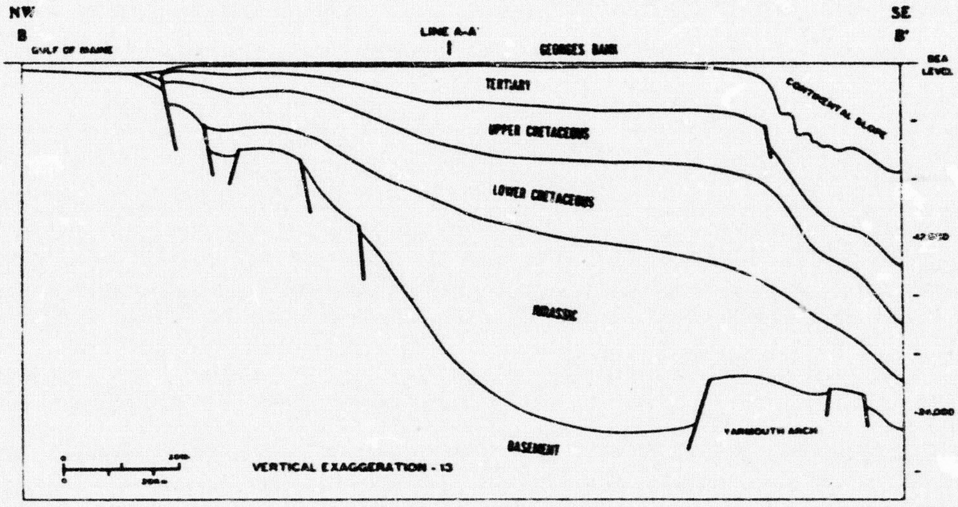

NW
B
GULF OF MAINE
LINE A-A'
GEORGES BANK
SE
B'
SEA LEVEL
TERTIARY
CONTINENTAL SLOPE
UPPER CRETACEOUS
LOWER CRETACEOUS
-12,000
JURASSIC
-24,000
YARMOUTH ARCH
BASEMENT
VERTICAL EXAGGERATION - 13

FIG. 8. Dip section of Georges Bank basin. Normal to coastline and shelf edge. Vertical exaggeration 13 to 1. (from Schultz and Grover, 1974).

Although Jurassic strata beneath Georges Bank may contain evaporites, diapiric salt structures similar to those found beneath the Scotian shelf have not been detected.

Extensive high-angle basement faulting appears to have affected only the lower several thousand feet of sediment. The Yarmouth arch, a basement feature that borders the trough on the southeast, appears to have been fault-controlled.

Elsewhere in the north Atlantic region, Emery (1965) suggested that favorable hydrocarbon-bearing structures may be associated with the basement ridge at the edge of the shelf, and a major fault inferred from geophysical data to extend just southeast of New York City.

(c) Geologic Hazards

The eastern coast of the United States is generally considered to be aseismic or relatively free from major earthquake occurrence. In 1755, however, a major earthquake occurred at Cape Ann, Massachusetts. This quake was rated at an intensity of VIII on the modified Mercalli-scale (Wood and Newmann, 1931)--a subjective scale of earthquake intensity based on observable effects 1/ Because of this earthquake, the coastal areas of Massachusetts and New Hampshire are placed in Zone 3 of NOAA's Seismic Risk Map (Algermissen, 1969) (Fig. 9) where major earthquake damage may occur. The southern coast of Maine lies in Zone 2, while the northern Maine coast falls in Zone 1, where only minor damage can be expected.

1/ A rough correlation of earthquake intensity (Modified Mercalli scale) with earthquake magnitude (Richter scale) is given as follows:

Magnitude	2	3	4	5	6	7	8
Max. intensity	1-11	111	V	VI-VII	VII-VIII	IX-X	XI

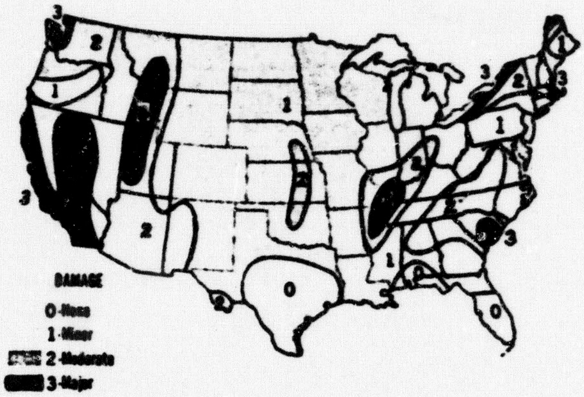


Figure 9. Seismic risk map for conterminous United States. (from Algermissen, 1969).

Although the Cape Ann earthquake occurred along a northwest-southeast trending zone of activity that, when projected to the southwest, crosses the central portion of Georges Bank, the absence of recorded activity in this region suggests that little offshore seismic hazard exists.

Other geologic hazards which may affect pipeline structure placements are the irregular topography, relatively thick cover of unconsolidated sediments, occasional presence of boulders, and shifting surface sediments caused by the unusual bottom current regime. Geopressures and the possible presence of shallow gas constitute additional potential hazards.

(2) Mid-Atlantic OCS

(a) General

The Mid-Atlantic OCS region has been arbitrarily defined as that portion of the East Coast continental margin which lies between 35°N and 40°N latitudes. Within this area, the continental shelf varies in width from 85 miles (140 km) off New Jersey to as little as 15 miles (25 km) off Cape Hatteras. The shelf break occurs at water depths of about 140 meters off central New Jersey but only 55 meters off Cape Hatteras.

The East Coast shelf displays a great variety of morphologic features. Uchupi (1968) classified these as either erosional features such as channels and terraces, or depositional forms, e.g. ripples and sand waves. The erosional features are generally relict, dating from extended periods of lowered sea level that characterized the later stages of the Pleistocene Epoch. Many of the relict stream channels are now filled with sediment.

The sand ridges occur in water depths generally less than 30 meters. Many of the nearshore ridges have been historically active, migrating over considerable distances in response to storm-generated currents and intense wave activity. Further offshore, the ridges and swales are probably relic features modified somewhat by modern tidal and storm activity.

Figure 10 shows the general distribution of former shoreline terraces, submerged river valleys and submarine canyons that characterize the mid-Atlantic OCS region, while Fig. 11 depicts the extensive occurrence of linear sand ridges and swales.

Coastal Features

Embayed estuaries and barrier islands are the dominant coastal features of the mid-Atlantic region. Delaware and Chesapeake Bays are the largest estuaries on the East Coast and represent drowned river channels dating from the Pleistocene. Although these bays drain an extensive land area, suspended sediment input is comparatively less than that discharged into more southern coastal embayments.

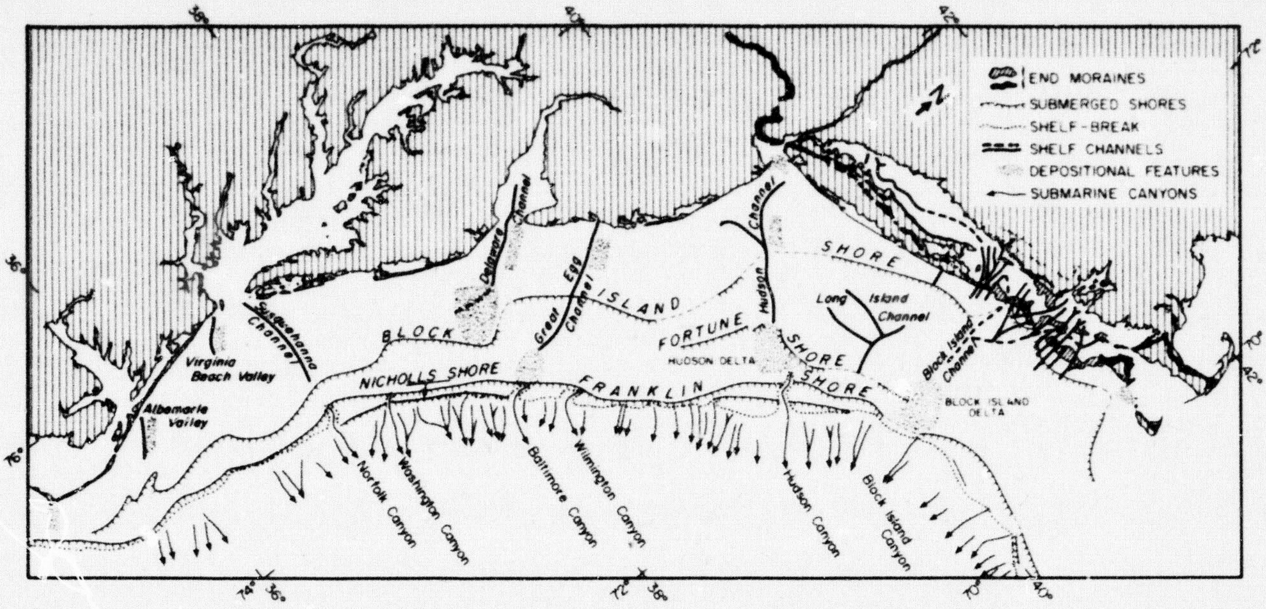

END MORAINES
SUBMERGED SHORES
SHELF-BREAK
SHELF CHANNELS
DEPOSITIONAL FEATURES
SUBMARINE CANYONS
N
Susquehanna Channel
Virginia Beach Valley
Albemarle Valley
Delaware Channel
Great Egg Channel
Hudson Channel
Long Island Channel
Block Island Channel
BLOCK ISLAND SHORE
FORTUNE SHORE
NICHOLLS SHORE
FRANKLIN SHORE
HUDSON DELTA
BLOCK ISLAND DELTA
Norfolk Canyon
Washington Canyon
Baltimore Canyon
Wilmington Canyon
Hudson Canyon
Block Island Canyon
38°
40°
42°
36°
76°
74°
72°
70°

Figure 10. Schematic chart of the various morphologic features on the continental shelf (excluding sand ridges and swales) and upper slope. Dashed shelf channels are filled with sediment. (from Milliman, 1973).

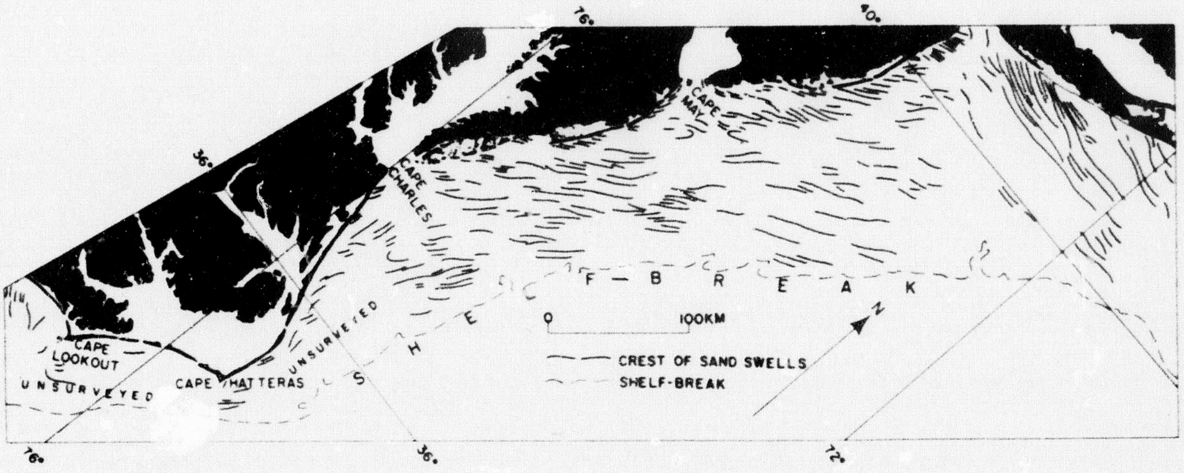

76°
40°
36°
72°
CAPE MAY
CAPE CHARLES
CAPE LOOKOUT
CAPE HATTERAS
UNSURVEYED
UNSURVEYED
SHELF-BREAK
0
100KM
N
CREST OF SAND SWELLS
SHELF-BREAK

Figure 11. Sand ridges and swales on the shelf between Long Island and Cape Hatteras (from Milliman, 1973; after Uchupi, 1968).

Barrier islands form a more or less continuous chain stretching from western Long Island to Cape Hatteras. The islands are generally long and thin (<1 km) with elevations usually less than 4 meters; local dune elevations may exceed 10 meters. Composed primarily of sand, these islands may have been formed either during the Holocene transgression (rise in sea level) or, as a result of longshore drift and seaward progradation over the shelf. Seasonal storm activity commonly causes cyclic migration in the relative shoreline position of these barrier islands, with little apparent net change over a complete cycle. Modern barrier spits associated with many of the islands appear, however, to be migrating along the shoreline as well as eroding landward.

Structure

The structure of the mid-Atlantic OCS region represents essentially a southward continuation of trends evident in the northern Atlantic region beneath Georges Bank. The section thickens considerably offshore southern New Jersey where Mattick et al. (1974) estimate about 12 km of undeformed post-Jurassic and Jurassic sedimentary rocks fill the Baltimore Canyon trough. Additional thicknesses of Triassic strata may be present at the base of the trough.

Figure 12 shows a generalized cross-section through the Baltimore Canyon trough area.

(b) Hydrocarbon Potential

Much of the future petroleum potential of the Mid-Atlantic OCS region is related to the thick Mesozoic and Cenozoic sediment accumulation that fills the Baltimore Canyon trough. Stratigraphic interpretation of these sediments is based primarily on the correlation of offshore geophysical data with onshore well data. These correlations suggest that Jurassic strata may be as much as 15,000 feet thick, and may contain significant amounts of carbonates and evaporites. Cretaceous sediment thickness may approach 20,000 feet, while the overlying Tertiary section probably does not exceed 6,000 feet in thickness. Onshore well data suggest a general tendency for Lower Cretaceous and Jurassic strata to thin considerably, westwards and become more clastic in nature, thus forming good stratigraphic trapping potential.

Several types of potential petroleum entrapment features may exist in the Baltimore Canyon trough area. These include: anticlinal traps associated with deep-seated intrusive bodies, reef traps and pinchouts of stratigraphic units against buried erosional surfaces, and fault traps associated with the basement ridge to the east. In addition, gravity measurements suggest the possible presence of diapiric salt structures within the trough.

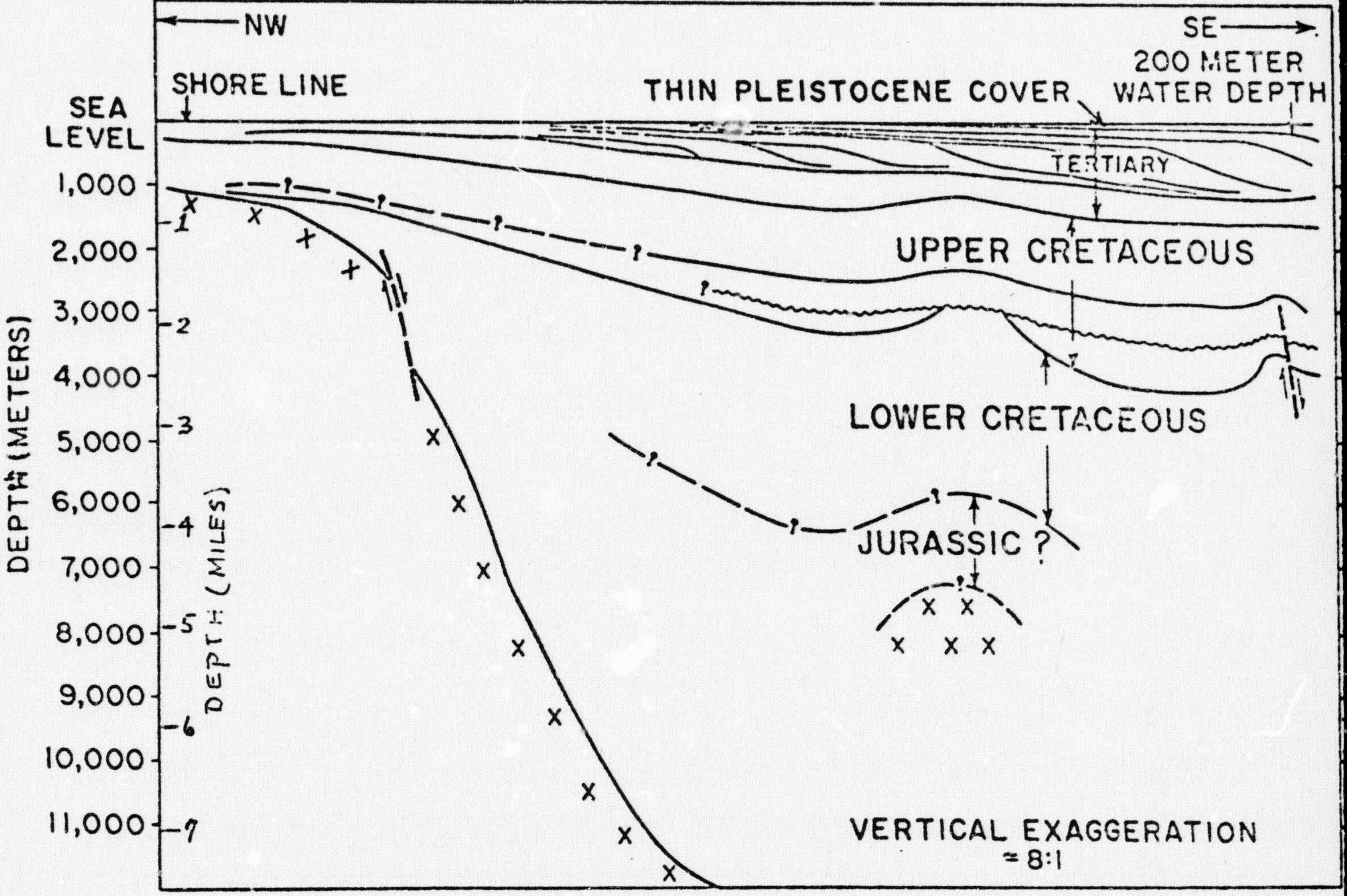

NW
SE
200 METER WATER DEPTH
SHORE LINE
THIN PLEISTOCENE COVER
SEA LEVEL
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
DEPTH (METERS)
DEPTH (MILES)
1
2
3
4
5
6
7
TERTIARY
UPPER CRETACEOUS
LOWER CRETACEOUS
JURASSIC ?
VERTICAL EXAGGERATION ≈ 8:1

Figure 12.--A composite, diagrammatic cross section through Baltimore Canyon trough illustrating potential petroleum entrapment features.

Source: R. E. Mattick et al., 1973, p. 29.

On the negative side, high seismic velocities shown by the older Mesozoic strata may indicate that potential reservoir strata have low porosities (Mattick, et al., 1974).

(c) Geologic Hazards

The mid-Atlantic OCS is characterized by few potential geologic hazards. The coastal region lies in seismic risk Zone 1, and is thus characterized by only minor risk of earthquake damage.

The most significant potential geologic hazard in this region concerns the transient nature of inner shelf sediments; both the linear ridges and nearshore barrier islands are susceptible to pronounced morphologic change during severe storm activity. Of additional concern are the moderate relief, random distribution, and unconsolidated character of these sedimentary features.

Abnormally high subsurface pressures (geopressures) may be encountered during drilling.

(3) South Atlantic OCS

(a) General

The East Coast continental margin south of Cape Hatteras represents a unique and complex assemblage of varied physiographic features. The East Coast shelf widens southward from 25 km off Cape Hatteras to 132 km at latitude 31°, then narrows again to about 3 km off West Palm Beach, Florida. South of Cape Lookout, the shelf is flanked by the Florida-Hatteras slope, a relatively smooth incline that drops off from a few meters in the north to more than 700 meters in the south, onto the Blake Plateau.

(b) Hydrocarbon Potential

The Southeast Georgia Embayment area is a downwarped continental margin geosyncline filled with Jurassic through recent sediments deposited in a seaward-thickening prism. Faulting may be present but currently, patterns are unknown. Seismic refraction data suggest the presence of a basement ridge or fault block near the shelf/slope margin. As shown in Fig.13 this area is contiguous with a much deeper trough under the adjacent Blake Plateau. Both areas are probably chiefly underlain by Cretaceous carbonate and clastic sediments. In general, very little is known about this basin as far as petroleum potential and structure.

(c) Geologic Hazards

The extensive distribution of sand waves that characterize the inner shelf surface of the north and central Atlantic regions extends also over the southern shelf area. The discussion of potential hazards related to shifting sediments in these other areas would apply equally to the south Atlantic region.

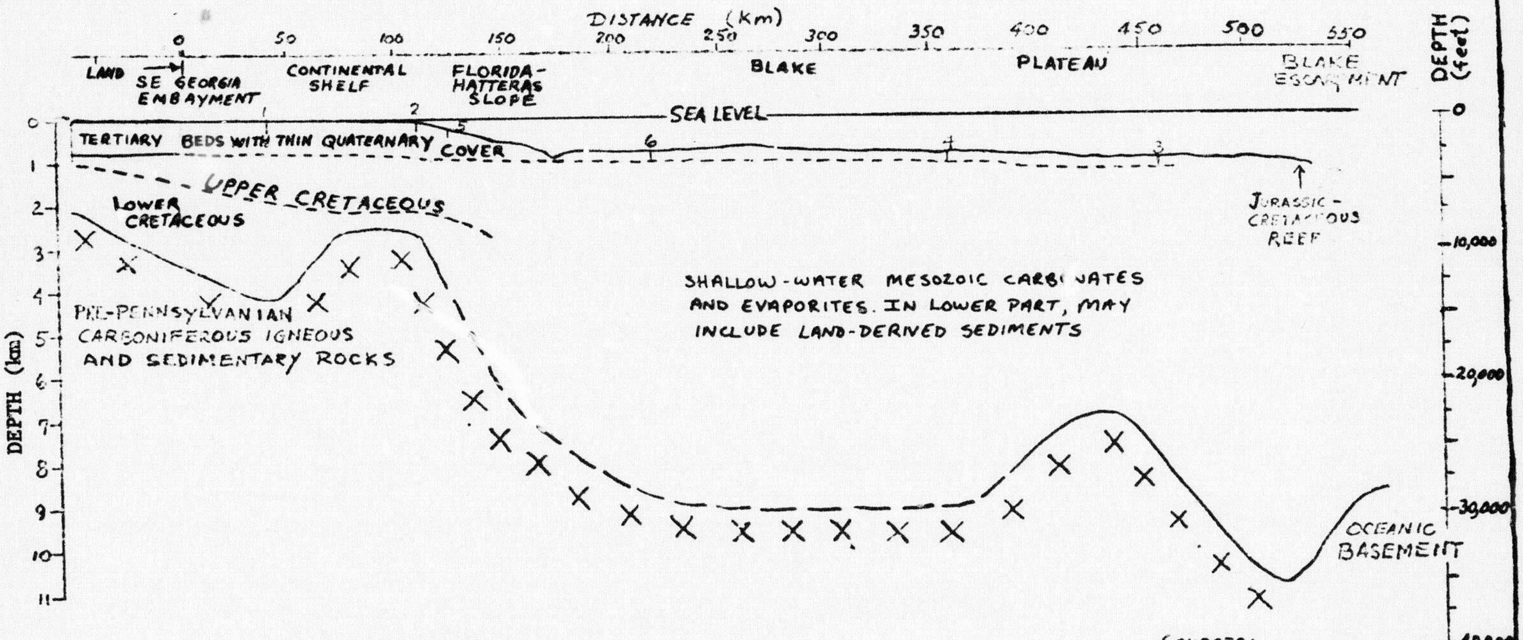

DISTANCE (Km)
0
50
100
150
200
250
300
350
400
450
500
550
DEPTH (feet)
LAND
SE GEORGIA EMBAYMENT
CONTINENTAL SHELF
FLORIDA-HATTERAS SLOPE
BLAKE
PLATEAU
BLAKE ESCARPMENT
SEA LEVEL
1
2
5
6
4
3
TERTIARY BEDS WITH THIN QUATERNARY COVER
UPPER CRETACEOUS
LOWER CRETACEOUS
PRE-PENNSYLVANIAN CARBONIFEROUS IGNEOUS AND SEDIMENTARY ROCKS
SHALLOW-WATER MESOZOIC CARBONATES AND EVAPORITES. IN LOWER PART, MAY INCLUDE LAND-DERIVED SEDIMENTS
JURASSIC-CRETACEOUS REEF
OCEANIC BASEMENT
DEPTH (km)
0
1
2
3
4
5
6
7
8
9
10
11
0
10,000
20,000
30,000
40,000

Figure 13. CROSS SECTION ACROSS SOUTHEAST GEORGIA EMBAYMENT AND BLAKE PLATEAU

SOURCES:
J.C. MAHER, 1971, FIG. 8,
K.O. EMERY AND E. UCHUPI, 1972, FIG. 94

Various parts of the south Atlantic coastal region are characterized by seismic risk values from 0 (central and southern Florida) to 3 (South Carolina). The South Carolina designation resulted primarily from a Modified Mercalli IX-X seismic event that occurred in 1886 near Charleston. Several other less severe (V-VII) earthquakes have occurred along the South Atlantic coast, primarily in South Carolina (Department of Commerce, 1973).

Geopressures may be encountered in some regions of the South Atlantic OCS. The possible presence of hydrogen sulfide and lost circulation zones to depths of 3000 feet must also be recognized.

Since most drilling on the Blake Plateau would have to be done in water depths exceeding 600 meters, this area does not have as high an economic appeal as potential areas of the more northern Atlantic OCS.

b. Climate of the Atlantic Coastal Area

(1) General Climatology and Seasonal Weather Patterns

The position and intensity of the Bermuda-Azores high pressure system for the most part controls the general surface weather patterns along the Atlantic coast. Major low pressure systems usually move in a north to northeast direction through the area. These storms occur most frequently during the winter season when the Bermuda-Azores high is far to the southeast, and may persist in an area for several days, generating high winds and sea states. The most severe storm systems occurring in the Atlantic area are classified as hurricanes, which bring abnormally high storm tides and seas simultaneously. Eighty percent of the hurricanes occurring between 1886 and 1972 occurred between August and October. The probability of winds exceeding 80 knots and 100 knots is 0.05/year and 0.01/year, respectively (CEQ, 1974).

The climate of the region from Cape Hatteras to Cape Canaveral is mild and maritime (cool moisture-laden sea breezes, moderate summer and winter temperature systems). Average summer/winter temperatures range from $78^{o}/45^{o}$F. at Cape Hatteras to $82^{o}/60^{o}$F. at Cape Canaveral.

Moderate summer temperatures in the Cape Hatteras region are attributed to the proximity of the cooler Virginia coastal water mass between the coast and the western edge of the Gulf Stream. Sea breezes further moderate summer temperatures with breezes blowing onshore during the day and offshore at night.

The middle Atlantic region from Cape Hatteras to Sandy Hook, New Jersey experiences latitudinal effects with annual average temperatures approximately 8^{O}F. warmer at Norfolk, Virginia than at Quonset, Rhode Island. Average temperatures range from 38^{O}F. at Quonset and 46^{O}F. at Norfolk in winter to 68^{O}F. at Quonset and 76^{O}F. at Norfolk in summer. Sea breezes again moderate onshore conditions, providing a mechanism for warming the coast during cooler months and cooling the coast during the warmer months (URI, 1973).

The North Atlantic area between Sandy Hook, New Jersey and the Bay of Fundy, Nova Scotia is a region characterized by rapid weather changes. This area lies in the global zone of westerly winds (the westerlies) in the general path of tropical air masses moving from the Gulf of Mexico. During the winter, onshore winds tend to maintain higher temperatures along the coast. During the summer this same mechanism exists to cool the coastal areas due to differences in the rate of cooling of water and land. Average annual temperatures for the region vary from about 40°F. in northern Maine to about 50°F. in the southern New York Bight (TRIGOM, 1974).

(2) Sky Cover and Visibility

Heavy fog occurs at land stations in the central Atlantic region between Cape Hatteras and Cape Canaveral. Along the southern Atlantic coast, offshore the area reports visibilities of less than 5 miles about 2% of the time. These visibility records include the effects of haze, fog, high relative humidity and precipitation.

The northern portion of the Central Atlantic region has reduced visibility more often than the central or southern Atlantic States. Fog and haze in northern reporting stations (Quonset, New York, and Atlantic City) cause visibilities of less than 2 nautical miles 25% of the time during May, June, and July. Boston has a higher frequency of reduced visibility (less than 2 nautical miles) than does any other area in the North Atlantic region. Snowfall can also cause significant visibility reductions locally throughout the winter months in the North Atlantic region.

Sky Cover

Average annual sky cover for the Atlantic Coast ranges from slightly over 50% at Miami to slightly less than 60% in the Gulf of Maine. There is little seasonal variation at each reporting station but generally the summer months in South Atlantic and North Atlantic regions reflect higher values than the rest of the year (10% to 20% higher). Winter and late fall are the seasons of maximum cloudiness in the central Atlantic region (U.S. Dept. of Commerce, 1968).

(3) Surface Wind Patterns

The general wind pattern along the Atlantic coast is strongly influenced by the position and intensity of the Bermuda-Azores High pressure system.

Summer winds along the Atlantic coast are generally from the southwest at 8 to 12 knots, except winds south of Cape Canaveral are predominantly from the east.

The winter pattern for Atlantic Coast surface winds is more complex. Winds south of Cape Canaveral are predominantly from the southeast at 10 knots; southwesterly at 10 knots from Cape Canaveral to the Georgia-South Carolina border; northeasterly at 9 to 15 knots from the South Carolina-Georgia border north to Delaware Bay; and northeasterly at 10 to 20 knots from the Delaware Bay north to the Bay of Fundy, (U.S. Dept. of Commerce, 1968a).

(4) Air Temperatures

Average winter temperatures range from 70°F. at Key West to approximately 20°F. in the northern portion of the Gulf of Maine. Winter latitudinal effects indicate a loss of 10°F. from 25°N to 30°N; 12°F. from 30°N to 35°N; 15°F. for 35°N to 40°N; and 12°F from 40°N to 45°N. Average daily ranges in temperatures are generally between 15°F. and 20°F. along the entire Atlantic coast.

Coastal summer average temperatures range from 82°F. at Key West to 65°F. in the northern portion of the Gulf of Maine. Latitudinal effect is not as significant on coastal summer temperatures as on winter temperatures. Temperatures are essentially the same from 25°N to 35°N. A drop in surface air temperatures of 5°F. is experienced from 35°N to 40°N, and 10°F. from 40°N to 45°N.

(5) Precipitation

Average total annual precipitation along the Atlantic coast generally ranges from 43 to 45 inches for most of the coastline with few exceptions (U.S. Dept. of Commerce, 1968a). Most of the rainfall in the South Atlantic region occurs during summer convectional thunderstorm activity. Hail frequently occurs during severe thunderstorms. Precipitation in the North Atlantic region results more frequently from cyclonic frontal air mass activity.

Throughout the Atlantic regions the fall season tends to be slightly wetter than the rest of the year. Large annual variations in total precipitation may occur due to large persistent storms or long term droughts (TRIGOM, 1974). Snowfall is latitude-related with an average of 2 inches/year at Cape Hatteras to between 60 and 100 inches/year along the Maine Coast.

(6) Storms and Storm Surge

The entire Atlantic coast experiences cyclones (storms occurring around low pressure centers having counterclockwise winds). Tropical cyclones, which include hurricanes, originate from 10°N to 30°N latitude where relatively warm 80°F. surface waters serve as sources of formation energy. A total of 290 hurricanes (storms with winds in excess of 64 knots) have been observed from 1901 to 1963. The peak time for tropical storms is from June to October. The maximum occurrence of these phenomena is in August and September when an average of 8 hurricane days and 15 tropical storm days (winds of 34 to 64 knots) occur. The Central and South Atlantic regions lie within the primary track of these storms.

Storms may produce large wind waves in conjunction with storm surges. Storm surges are elevations in sea level formed by lowered atmospheric pressure and the piling up of wind-driven water on the coastline (Edinger, 1967). The magnitude of these storm surges may be increased by greater land run-off from heavy rains. The destructiveness of storm surges and heavy seas is at a maximum where coasts are low lying and densely populated.

c. Physical Oceanography

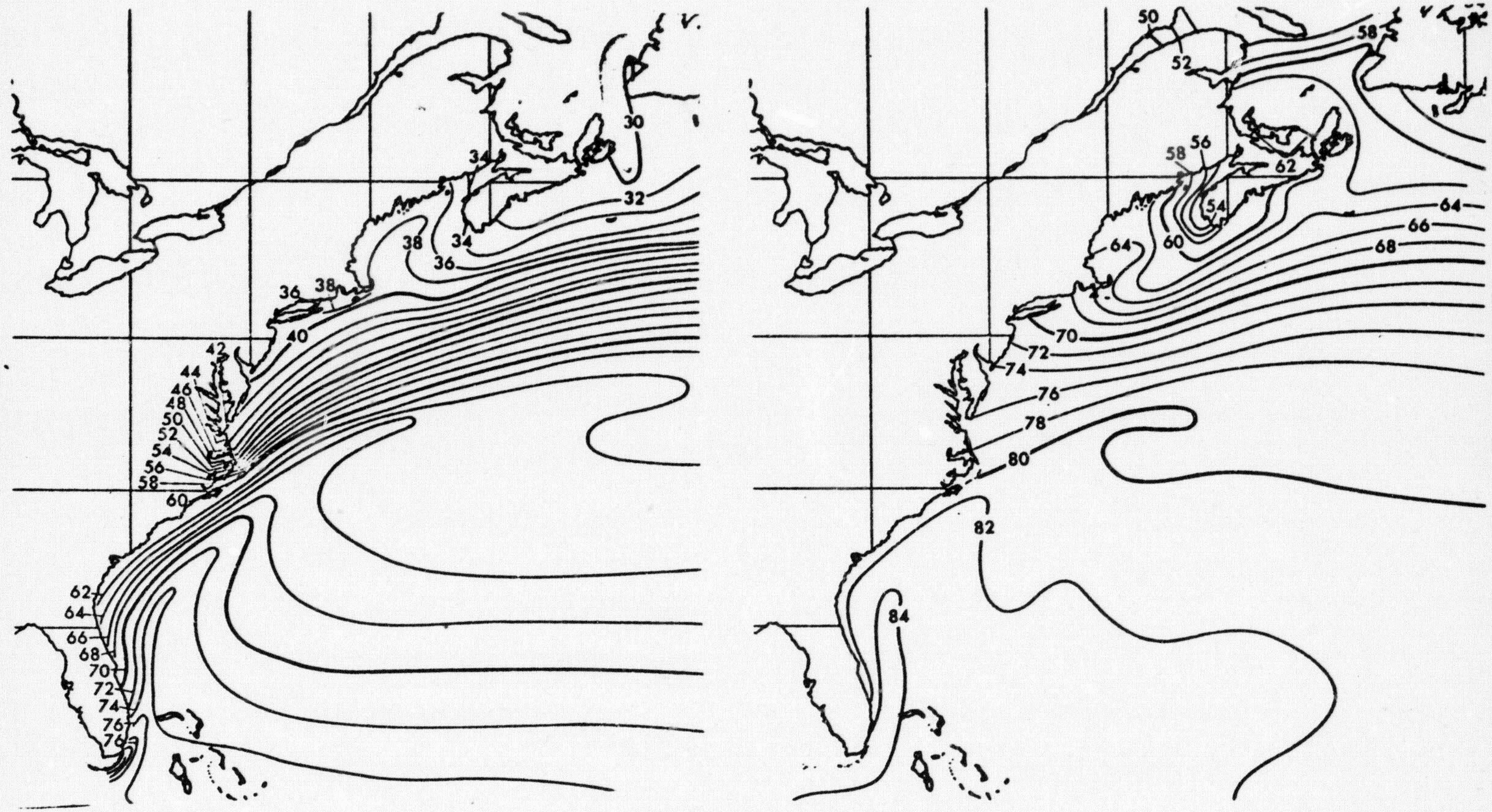
The shelf hydrography of the South Atlantic region is influenced by two major factors: the Gulf Stream and the prevailing weather. The Gulf Stream flows from the Straits of Florida northward along the shelf break and supplies of shelf waters with warm saline water. Water from the Gulf Stream enters the shelf waters by irregular meanders or lens formations (discrete parcels retaining the physical properties of their origin waters).

Shelf waters occurring off the Central Atlantic coast are formed from waters flowing southward along the coast and river effluents from the major coastal estuaries both within the region and to the north. Discrete parcels of water (lenses) are broken off the western edge of the Gulf Stream and move westward over the shelf where they ultimately become mixed with the shelf waters. In the North Atlantic region, water enters the shelf from three major sources: 1) the Bay of Fundy, 2) the western basin of the Gulf of Maine, and 3) estuarine discharges.

(1) Surface Sea Temperatures

Figures 14 and 15 represent average sea surface temperatures for February and August based on data collected from 1854 to 1958.

The surface isotherms (lines of equal temperature) parallel the coast in the South Atlantic region, with temperatures increasing with distance offshore. During the winter months this gradient of tempera-


30
32
34
34
36
38
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
76
50
52
58
56
58
62
54
60
64
64
66
68
70
72
74
76
78
80
82
84

WINTER

SUMMER

FIGURES 14 and 15

MEAN SEA SURFACE TEMPERATURES (°F)

From U. S. Naval Oceanographic Atlas, H. O. No. 700, 1963.

turc is more defined because the coastal waters are much cooler than the Gulf Stream. As warming occurs during spring and early summer, this gradient becomes less sharp and by mid-summer, surface shelf waters are nearly isothermal. Autumn cooling reverses this trend rapidly and winter conditions are quickly reached. The water column approaches isothermal conditions from surface to bottom over the shelf during the winter. The maximum temperatures can be found at 150-250 meters along the slope with colder water above and below.

Irregular warming of the surface layers begins in late February. Initially this warming takes place throughout the water column with most rapid warming of the entire water column occurring near land. Beginning in late April, the surface layers are warmed much more rapidly than the underlying water, resulting in the formation of a thermocline (a steep vertical thermal gradient).

Autumnal cooling of surface water first results in the column approaching equal temperatures throughout. The speed of this cooling is determined by air temperature and wind induced water mixing. By middle November, surface sea temperatures become horizontally isothermal across the shelf. Depth of the thermocline is about 80 meters. Minimum temperatures are reached in late February.

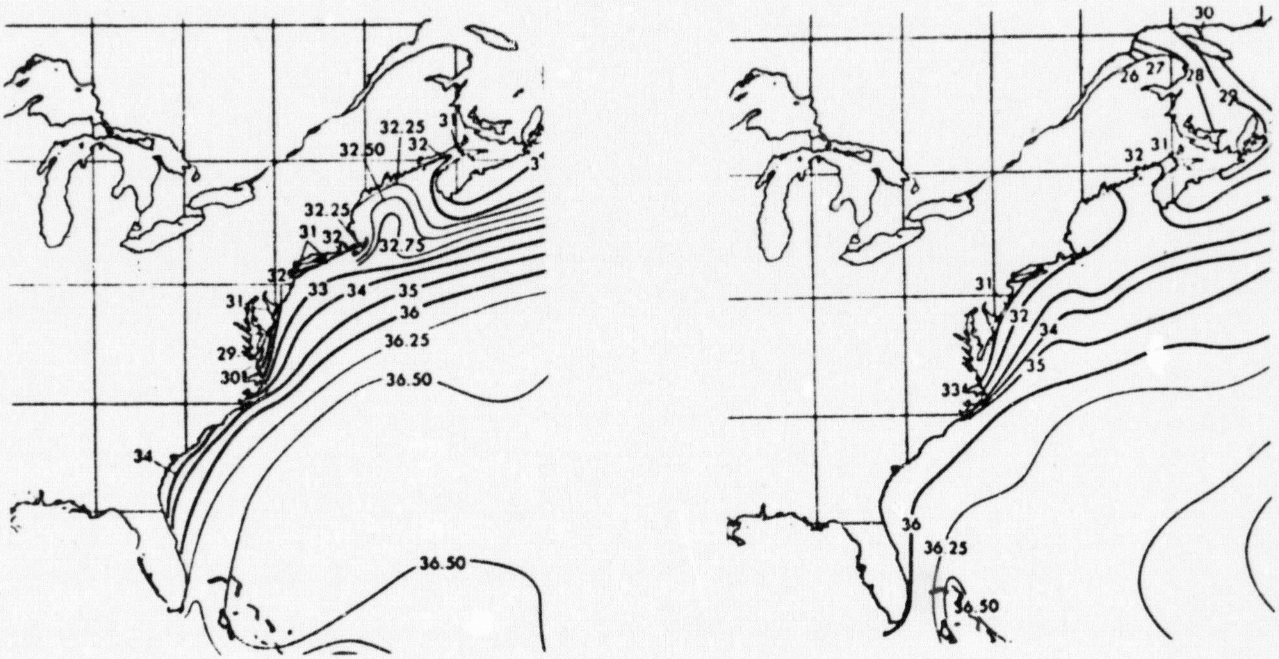
The Bay of Fundy and Georges Bank areas have sufficient tidal mixing to inhibit the formation of a summer thermocline. A large range of sea surface temperatures exists between the coastal water and slope water throughout the year. Slope waters show temperature gradients during winter, and essentially isothermal conditions during fall and spring, due to wind induced mixing.

(2) Salinity

Figures 16 and 17 present average winter and summer salinities. Low amounts of estuarine effluents and the proximity of the Gulf Stream contribute to the high salinity of shelf waters south of Cape Hatteras. Surface salinity contours are variable, but generally parallel the coastline with salinities increasing offshore to 36 ppt at the western edge of the Gulf Stream. Highest salinities occur along the entire coast during summer and fall.

Stefansson *et al*. (1971) have calculated that with strong persistent northeast winds driving Virginia water south of Cape Hatteras, the shelf experiences complete replacement of water on the order of 14 days.

North of Cape Hatteras, shelf waters show little longshore difference in salinities from the Bay of Fundy to Cape Hatteras. The annual salinity variation is caused by fresh water runoff and intrusion of


32.25
31
32.50
32
32.25
31
32
32.75
32
33
34
35
36
36.25
36.50
31
29
30
34
36.50
30
26
27
28
29
32
31
31
32
34
35
33
36
36.25
36.50

WINTER

SUMMER

FIGURES 16 and 17

MEAN SEA SURFACE SALINITY

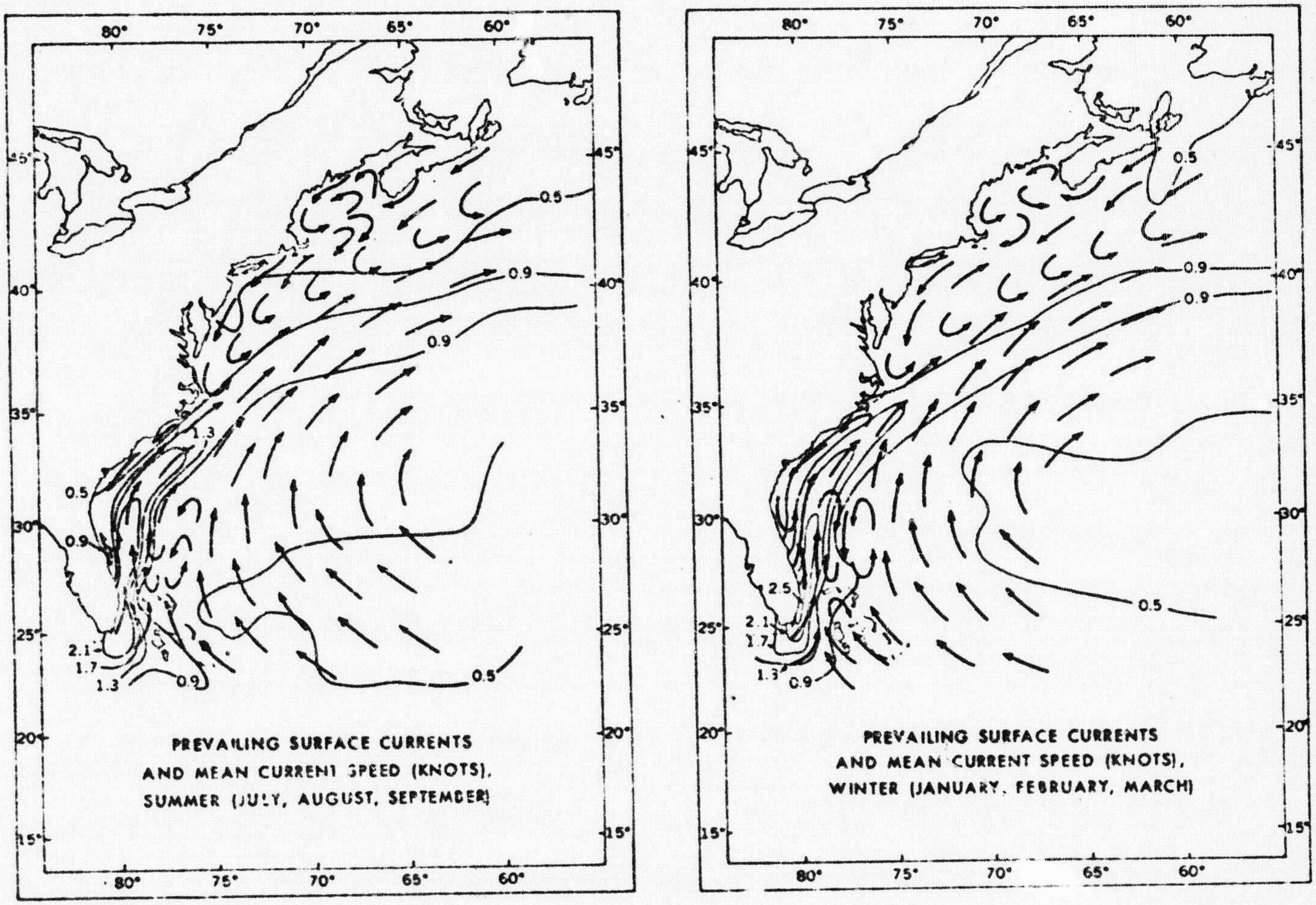
From U.S. Naval Oceanographic Atlas H. O. 700 , 1963.

saline waters from the slope. During the spring season of peak runoff, a shoreward band of less than 32 ppt salinity water is formed. Waters of less than 32 ppt salinity may be found 100 miles seaward of the mouth of Long Island Sound and 50 miles from the mouth of Chesapeake Bay. Steep vertical salinity gradients develop on the shelf during these freshening conditions, which normally remain through July and August. Turbulence hinders formation of steep salinity gradients on Nantucket Shoals throughout the year.

Autumnal cooling of surface waters weakens the stability of the water column across the shelf, permitting greater vertical mixing. Mixing results in increased surface salinity and dissipation of low salinity water-cells near the mouths of major estuaries. The winter pattern of salinities is normally established by December.

(3) Surface Circulation

Shelf circulation south of Cape Hatteras is controlled primarily by the Gulf Stream, winds, and freshwater inflows from the coastal estuaries (Figures 18 and 19). Tidal currents are weak and rotary (showing directional flow throughout the tidal cycle) producing slight influence on shelf circulation. The Gulf Stream flows to the northeast, with surface velocities of 2 knots (102 cm/sec) at the edge of the shelf. Nearshore currents flow to the south during most of the year.


80°
75°
70°
65°
60°
45°
40°
35°
30°
25°
20°
15°
0.5
0.9
1.3
1.7
2.1
2.5
PREVAILING SURFACE CURRENTS AND MEAN CURRENT SPEED (KNOTS), SUMMER (JULY, AUGUST, SEPTEMBER)
PREVAILING SURFACE CURRENTS AND MEAN CURRENT SPEED (KNOTS), WINTER (JANUARY, FEBRUARY, MARCH)

FIGURES 18 and 19

Mean Surface Currents Summer and Winter (Atlantic Ocean)
Modified from U. S. Naval Oceanographic Atlas H. O. 700, 1963.

In general, a northerly drift over the entire southern shelf exists in the cooler months except in the vicinity of Cape Hatteras where local wind effects predominate. A reversal of this pattern has been observed for the warmer months, with a southerly flow predominant.

Surface currents on the Middle Atlantic Bight shelf flow southward at speeds of approximately 0.4 knots (20 cm/sec.). The surface current is, in part, a result of density gradients across the shelf and local persistent wind conditions.

Surface circulation patterns are more complex along the North Atlantic region shelf. In this region, major river runoff, complex bathymetry, seasonally high winds, intrusion of slope water, and tidal actions combine to produce these complex circulation parterns. Generally a westward current is formed on the slope opposing a northeastward current of slope water adjacent to the Gulf Stream. This westward drift joins the Georges Bank eddy (a circular current formed when currents pass over obstructions) on the southern edge of the Bank. This flow splits, one portion moving westward across the shelf to the area off Rhode Island, the other portion moving northward to become entrained in an eastward flow moving across the northern edge of Georges Banks. A southerly flowing limb closes the eddy on Georges Bank. A counterclockwise Gulf of Maine eddy occurs just north of Georges Banks. This eddy, like the Georges Bank eddy, is also seasonal, slowing by summer with the southern limb dissipating into a flow across Georges Banks during autumn and winter. Surface currents in the Gulf of Maine are slow in winter and spring, increasing during the summer and decreasing during the fall.

Moderate to large storm systems can greatly modify normal circulation patterns both by wind induced currents and by increased coastal runoff.

(4) Tides

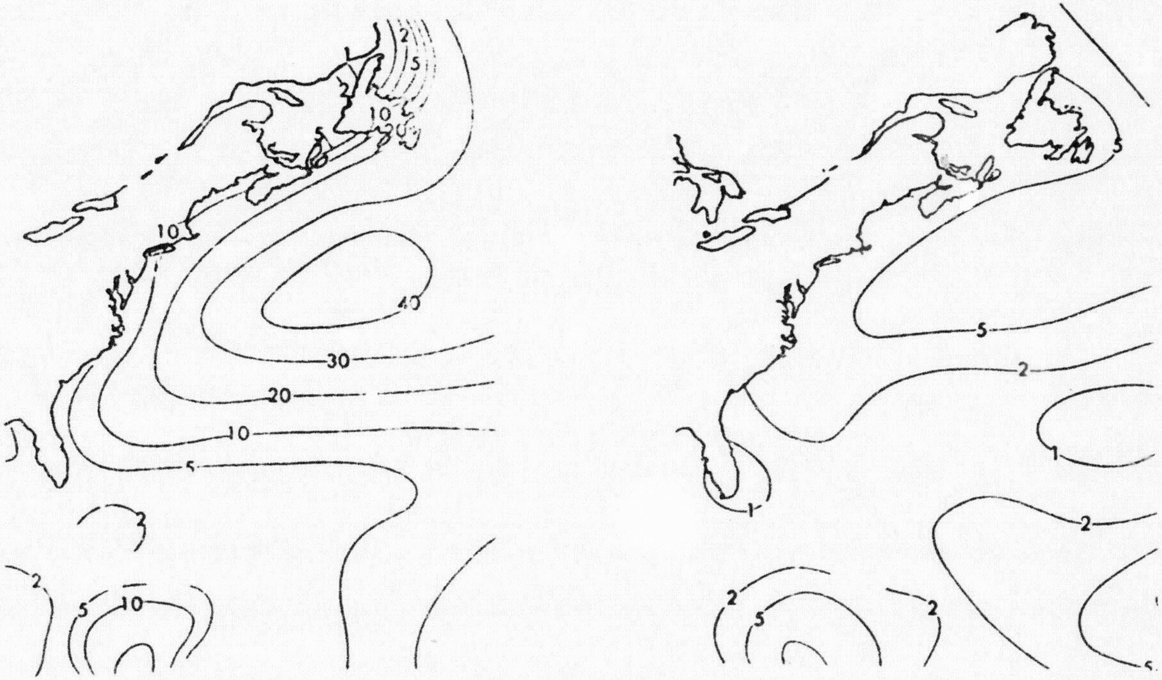
Tides are fluctuations in sea level due to the gravitational attraction of the moon and, to a lesser extent, the sun. Bottom friction and local bathymetric features influence the amplitude and periodicity of the tides. Nearshore and shoreline bathymetry modifies the tides by restricting their normal passage, resulting in surface level build-up (high tides) and local currents. Offshore, tides are usually quite indiscernable.

Spring tides (the highest tides of the month) occur during the full and new moons, while neap tides (the lowest tides of the month) occur during the first and third lunar quarters. Along the entire East Coast, tidal motion is semidurnal, having two complete cycles every lunar day (24.8 hours). Spring tidal heights vary from 4 feet at Cape Canaveral, 8 feet at Savannah, to 3 feet at Cape Hatteras. Tidal heights along the South Atlantic region seldom exceed 2 feet. Along the North Atlantic coast, where basins and other bathymetric restrictions are common, tidal heights are correspondingly modified. At Boston Light, the spring tidal range is 9 feet and at Eastport, Maine, it is 20 feet.

(5) Sea and Swell

Surface waves are produced mainly by surface winds and modified by other factors. Wave size is a function of wind speed, (the period of time the wind has been blowing steadily from a given direction), and the fetch (the distance of unobstructed water subject to the wind force). Waves occur only in the area under the influence of the generating wind. Swell is a term used for decaying waves that are no longer under the generating influence of surface winds. Both sea and swell are generally encountered simultaneously at any given location.

Average wave conditions for the U.S. Atlantic coast are contained in Figures 20 and 21. Maximum theoretical wave heights (assuming unlimited fetch and duration) are: a wave exceeding 51 feet every 2 years, 71 feet every 5 years, 84 feet every 10 years, 100 feet every 25 years and 112 feet every 50 years (U.S. Dept. of Commerce, 1973a). A wave exceeding 112 feet in height was reported by the U.S.S. Ramapo, in 1933 (Bascom, 1964).


2
5
10
20
10
40
30
20
10
5
2
2
5
10
5
2
1
1
2
2
5
2
5

WINTER

SUMMER

FIGURES 20 and 21

PERCENT FREQUENCY OF SEAS > 8 FEET

From U. S. Naval Oceanographic Atlas H. O. No. 700, 1963.

Waves tend to "shoal" when the wave encounters water depths of less than one-half the wave length. Upon shoaling, the wave begins to steepen, slow down, and finally break when critical steepeness is reached (surf or breakers).

(6) Ice Conditions

Although ice conditions along the Atlantic coast are highly variable from year-to-year, bay ice can be expected in many of the bays and inlets as far south as Cape Hatteras from December through March, with greatest development occurring in February (U.S. Naval Oceanographic Office, 1968). Ice of sufficient thickness to hamper navigation normally occurs in the majority of Maine harbors under normal winter conditions.

d. The Biological Environment

The Atlantic coastline falls within four broad zoogeographic zones: 1) the Boreal which runs from Newfoundland to Cape Cod; 2) the Virginian which runs from Cape Cod to Cape Hatteras; 3) the Carolinian which extends from Cape Hatteras to Cape Canaveral; and 4) the Caribbean from Cape Canaveral southward. These zones are based upon the occurrences of species endemic (found only within the boundaries) to particular areas and correspond closely to zones which can be described by the physical characteristics of the sea water therein. The Gulf Stream and other currents have a profound influence on the seaward boundaries of these zones.

A classification of marine biota according to habitat and degree of self-mobility will be used in the following discussion.

The marine environment is broadly divided into the pelagic and benthic realms. The pelagic realm includes all ocean water above the bottom; over the continental shelf, these waters constitute the neritic province (as opposed to the oceanic province above the slope and deep ocean bottom). The benthic realm includes the sea bottom and sub-bottom environment.

The basic classification of marine life in the pelagic realm includes the plankton--those organisms which have insufficient mobility to overcome prevailing water currents, and the nekton--animals which are able to move against prevailing currents. Phytoplankton are the plant forms of plankton, and as such, are the basic synthesizers of organic matter in the oceans. Zooplankton are the animal forms of plankton and collectively comprise the primary consumers of the phytoplankton. Benthic biota, or benthos, refers to bottom-dwelling marine life. Representative Atlantic biota are listed in Table 6.

The water colum may be broken down into the photic zone (those layers which receive sufficient sunlifht for photosynthesis) and the aphotic zone (below the depth of light penetration).

Table 6. Representative Atlantic Biota

(1) Phytoplankton

a. South Atlantic
Diatoms. (Skeletonema, Leptocylindrus, Nitzschia)
Coccolithophores. (Coccolithus, Umhilicosphaera)
Dinoflagellates. (Gonyaulax, Amphidinium, Gymnodinium)

b. Gulf Stream and Shelf
Diatoms. (Skeletonema, Chaetoceros, Navicula, Rhizosolenia)
Dinoflagellates. (Amphidinusum, Ceratium, Gymnodinium)

c. Gulf of Maine
Diatoms. (Cascinodiscus, Chaetoceros)
Dinoflagellates (Ceratium)

(2) Zooplankton

a. South and Middle Atlantic
Copepods (small crustaceans). (Acartia, Labidocera, Paracalanus, Centropages, Eucalanus, Lucicutia, Temora)
Chaetognaths (arrow worms). (Sagitta, Pterosogitta)
Pteropods (mollusks).
Decapods (crustaceans like lobsters, crabs). (Callinectes)

b. Gulf of Maine
Copepods (small crustaceans). (Temora, Labifocera, Pseudocalanus Calanus, Acartia)
Cladocerans (small cruataceans). (Podon, Evadne)

(3) Benthic (bottom) Biota

a. South Atlantic
Echinoderms (starfish, urchins). (Mellita)
Polychaetes (segmented worms). (Macroclymene, Palaenotus, Megelona, Oniuphis)
Bivalves (clams,etc.). (Spisual)
Gastropods (mollusks like snails). (Olivella)
Annelids (worms). (Polygordius)
Amphipods (crustaceans). (Platyischnopus, Maera, Paraphaxus, Siphonoecoetes)

Table 6 (cont')

b. Central Atlantic Region
i) Sand fauna
Polychaetes (segmented worms). (*Spisula*, *Astarte*)
Gastropods. (*Polinices*, *Lunatia*)
Amphipods (crustaceans)
Decapods (crustaceans like lobsters, crabs). (*Cancer*, *Crangon*)

ii) Silty-sand fauna
Polychaetes (clams). (*Pherusa*, *Clymella*)
Bivalves (clams). (*Arctica*, *Carditan*)
Amphipods (crustaceans). (*Ampelisca*)
Anemone.

iii) Silty-clay fauna
Polychaetes.
Bivalves (clams, etc.)
Echninoderms (starfish, urchins). (*Briaster*, *Ophiura*)

c. North Atlantic
i) Sand Fauna
Bivalves (clams, etc.) (*Spisula*)
Echinoderms (starfish, urchins). (*Echinarachinius*)
Gastropods (mollusks like snails). (*Lunatia*, *Nassarius*)
Decapods (crustaceans like lobsters, crabs). (*Crangon*)

ii) Silty-sand fauna
Echinoderms (starfish, urchins). (*Amphioplus*, *Thions*)
Bivalves (clams, etc.). (*Arctica*)
Gastropods (mollusks like snails). (*Colus*)

iii) Mud-bottom fauna
Echinoderms (starfish, urchins). (*Briaster*, *Ophiura*)
Decapods (crustaceans like lobsters, crabs).

iv) Gravel-bottom fauna
Porifera (sponges). (*Cliona*, *Polymastia*)
Hydroids (plant-lile animals; corals are one example) (*Turbularia*)
Bivalves (clams, etc.). (*Modiolis*)
Echinoderms (starfish, urchins). (*Solaster*, *Crossaster*)
Tunicates (sea squirts)

(4) Nekton

a. South and Middle Atlantic
Fish. (Menhaden, Alewives, thread herring, also, see text)
Decapods (crustaceans like lobster, crabs). (*Callinectes*)
Elasmobranchs (sharks, rays)
Cetaceans (whales, porpoises)
Manatees.

Table 6 (cont')

b. Gulf of Maine
   Fish. (Flounders, scup, cod, hake, also, see text)
   Elasmobranchs (sharks, rays)
   Cetaceans (whales, porpoises)
   Pinnipeds (seals, sea lions). (Grey seals)

(5) Birds (see text)

(1) Phytoplankton

The occurrence and population levels of phytoplankton are governed by several factors including: 1) availability of nutrients; 2) physical parameters, such as light and temperature; 3) adaptability; 4) grazing pressures of zooplankton and other herbivores; and 5) water column stability.

Phytoplankton dynamics are incompletely understood on the Atlantic shelf. Insufficient data currently exist to give other than cursory comparisons of plankton populations.

The dominant (in terms of biomass) species of phytoplankton in typical Atlantic Ocean regions are given in Table 6.

Generally phytoplankton numbers decrease seaward from the coast. Nitrate (NO_3) nitrogen appears to be the limiting nutrient to the phytoplankton community since available nitrate is virtually completely incorporated within the living cells except near estuaries (Ryther and Dunston, 1971). The flora of the shelf is complex and relative abundances of species may change with time and area.

A thermocline (sharp vertical temperature gradient) exists in the waters of the Central Atlantic region. This thermocline, which occurs from late spring to early winter, limits circulation of nutrients from cooler waters up into the photic zone where they could become available to plankton. Throughout the existence of the thermocline, a continuous rain of dead animals and plants sinks from the photic zone. These nutrients are lost from the surface layer until upwelling or fall and winter wind-induced mixing occurs.

High productivity levels have been reported in December and March. During these months an 8-fold increase in populations (up to $3x10^8$ cells/liter) occurs over summer levels (URI, 1973).

Population levels of certain species of phytoplankton may reach phenomenal densities of $4x10^7$ cells/liter. Such an occurrence of certain species is called a "red tide". These high density explosions normally involve one or more of the dinoflagellate species. These blooms are widespread and common in the Gulf of Maine and along the Central and South Atlantic regions, especially in estuaries. Products excreted by these organisms reach sufficiently high concentrations to occasionally cause skin irritations and respiratory infections of people working near the water, massive fish kills, paralytic shellfish poisoning, and potential human mortality if shellfish exposed to sufficient levels of the excreted toxins are consumed. These blooms most often occur following high levels of freshwater runoff, warm water temperatures, and sufficient sunlight (VIMS, 1974).

(2) Zooplankton

The population dynamics and levels of zooplankton are also incompletely understood for the Atlantic region.

Zooplankton communities contain holoplankton and seasonal occurrence of large numbers of meroplankton. Zooplankton may be herbivores (feed on plants exclusively), carnivores (feed on animals only), or non-selective feeders (both). They show tendencies to undergo vertical diurnal migration which enables them some level of control over horizontal currents; however they do not possess the mobility to swim against prevailing currents.

Zooplankton can be split into two categories: neritic (found between the shore and the edge of the shelf), and oceanic (found seaward of the shelf). Organic zooplankton is generally composed of holoplankton, whereas the netritic community may be predominantly composed of seasonal meroplankters. The factors determining these boundaries include vitamins, coastal currents, planktonic excretions, temperature, salinity, nutrient levels, light levels, and others.

Bowman (1971, in VIMS, 1974) has described 100 spceies of copepods of the South Atlantic coastline. Eighty-one species were primarily oceanic and three relatively consistent species relationships were described for neritic organisms.

Two species of decapods and 19 species of pteropods have been described along the South Atlantic coast (Williams, 1969; Chen and Hillman, 1970). The presence of early-life cycle stages of the crab Callinectes has been reported in both shelf and oceanic areas (VIMS, 1974). Generally, the total number of plankton per unit area decreases in the offshore direction but diversity increases.

Seasonal shifts in phytoplankton communities occur in the Middle Atlantic region. Two major shifts occur annually causing a boreal community in the winter-spring, and a temperate-tropical community in the summer and fall. The occurrence of these communities appears predominantly controlled by temperatures which inhibit the reproduction of the temperate-tropical group during the cooler seasons. Salinity also affects species composition of the community but specific effects are unclear (URI, 1974).

Neritic zooplankton occur from shore to the 100 meter isobath (a line drawn along the contour of equal water depth values) along the North Atlantic region coastline. This includes most of the Gulf of Maine, and Georges and Browns Banks. Meroplankton forms are predominantly restricted to these waters.

A series of reports by Sherman (1966, 1968, and 1970) describes consistencies and variations in the zooplanktonic community from 1964 to 1968. These varied from year to year with respect to relative abundance and range. The deep basins in the Gulf of Maine are occupied by oceanic species. Winter cooling of surface waters results in reduced rates of reproduction and lessening in populations.

(3) Benthic Biota

Benthos may be classified as infauna--those organisms living within the bottom sediments, and epifauna--those which dwell upon the ocean bottom.

The distributions of benthic organisms are governed by complex interactions of physical and biological factors. Physical characteristics of the surficial sediments are a major factor in zonation. Hard substrates such as rock or wood actually support a more varied assemblage than do unconsolidated substrates (e.g., sand and mud). The presence of stresses such as bottom currents, wave induced turbulence, and pollution also are major factors in benthos zonation.

The shelf substrate of the South Atlantic Region is primarily composed of medium grained sand and shell, although silty sand occurs near the mouths of estuaries. The zoogeographic regions described in the section on plankton also apply to the benthos. The sharp temperature gradients at Cape Hatteras and Cape Canaveral mark the northern and southern boundaries of many organisms found in this region. Caribbean fauna exist throughout this region offshore the mid-shelf. The nearshore shelf (0-40 meters depth) is characterized by a detritus feeder community type, several filter feeders, and a few carnivores. The outer continental shelf (20-200 meters) is below normal wave action effects and the biota here are more complex. A total of 90 species were reported as prevalent in this zone by Day, et al. (1971). Polychaete worms are the most common taxonomic group, at times accounting for more than 50% of the total benthic biomass. The diversity commonly found in benthic studies is indicated by Leiper's work (1973 in VIMS, 1974) at three stations off Georgia which yielded a total of 322 species in 21 phyla.

Three level bottom biotic assemblages have been described for the Central Atlantic region. These are the sand, silty sand, and silt-clay assemblages. The sand fauna are found primarily from a depth of several to 30-50 meters. This sandy community type apparently extends from Cape Hatteras to Cape Cod and is also found on Georges Bank.

The silty-sand fauna are found over large areas of the shelf, and consists of polychaetes, bivalves, amphipods, and detritus-feeding crustaceans (see Table 6).

Silt-clay fauna are primarily restricted to estuaries and shelf areas at their mouths. This assemblage of organisms includes many deposit-feeding polychaetes, bivalves, and echinoderms.

The North Atlantic region contains two zones based upon temperature and salinity, the Boreal which extends from Newfoundland to Cape Cod and the Virginian which extends from Cape Cod to Cape Hatteras. Some species occur in both regions, however Cape Cod forms the boundary for most benthic organisms in this region.

Four community types have been described by Wigley (1968, in VIMS, 1974). These assemblages have been categorized by the substrate they most frequently colonize. They are the sand, silty-sand, mud-bottom and gravel types. The number of organisms in each of these community types is high.

(4) Active Swimmers - Nekton

Nekton is the term used to describe organisms which are capable of swimming against currents. Most of the nekton is comprised of fishes, marine mammals, molluscs, and crustacea.

The coastline of the Atlantic Coast is indented with numerous embayments. These estuaries are utilized by many of the commercially important fish species throughout the area. Shad, striped bass, and river herring are among the species occasionally found in tidal marshes. The young of these species use these estuary areas as feeding grounds. The larval and juvenile forms of the flounders, menhaden, sea bass, shrimp, eels, and mullet are transported into the estuaries from offshore spawning grounds. Fish which seasonally feed in the estuary include the shrimp, striped bass, flounders, menhaden, and others (TRIGOM, 1974). Clark et al. (1969) estimated that 60 - 70% of the commercially important Atlantic species utilize the estuaries during some period of their life-time.

The South Atlantic Region Shelf includes part of the Carolinean and Caribbean zoogeographic zones. The shelf is smooth, flat and sandy with the exception of several offshore areas and around the mouths of the estuaries where the bottom is normally muddy. The inshore area (less than 20 meter water depth) has been historically fished for shrimp, crabs, spot, croaker, kingfish, and sea trout. The offshore area is normally fished for the calico scallop, snappers, groupers, and porgies. Rock outcroppings and reefs, to be discussed later, are found off the coast of North Carolina. These hard substrates are isolated and provide productive snapper and grouper fisheries (VIMS, 1974).

The flatfishes (halibut, flounders, sole, plaice, and yellowtail) common along the Atlantic Coastline, may be considered as nekton, although they bury themselves in unconsolidated sediments. Roundfish or cod, tomcod, haddock, hakes, pollock, and others normally feed on crustacea, worms, mulluscs, and echinoderms which colonize specific types of substrates, thus these species normally are associated with specific bottom types. Preferences for specific substrate types are commonly shown by those species (Emery and Uchupi 1972).

Fish normally found in open waters include the bluefish, Atlantic mackeral, Atlantic menhaden, and the black bass. Anadromous (those species which swim into rivers to spawn) species, normally found in offshore waters, include the alewife and shad. Species of fish which inhabit both the offshore and estuarine waters include the striped bass, summer flounder, scup, weakfish, red drum, striped mullet, and tautog. Species which normally inhabit the estuarine areas throughout the year include the Atlantic croaker and the white pearch.

The Continental Shelf widens north of Delaware Bay and extends seaward to encompass Georges Bank and Brown Bank. Two distinct areas can be distinguished by salinity and water temperature. The cooler area of the Gulf of Maine results from rapid vertical water mixing and is characterized by boreal species. The warmer Mid-Atlantic Bight area is dominated by warm water species normally found in the Central Atlantic Region. A total of 196 species have been described as normally occurring within the North Atlantic Region. This figure represents 20% of the total number of species found along the Atlantic Coast (TRIGOM, 1974). The Gulf of Maine contains mostly endemic species while in the Mid-Atlantic Region, a diverse group of southern fishes move north to Cape Cod as spring warming occurs. A cold water barrier at Cape Cod is generated by upwelling between June and September. This area of cold water blocks the northern movement of southern species. During the cooler seasons, several species from the Gulf of Maine may be found on the Mid-Atlantic Shelf, however fewer species exist in this region during fall and winter than in the summer. The summer southern migrants which move north to Cape Cod include: summer flounder, scup, weakfish, kingfish, mullets, black seabass, filefishes, pompanos, and northern puffers. Some species which move northward around Cape Cod into the Gulf of Maine include the spiny dogfish, silver hake, red hake, white hake, American shad, striped bass, menhaden, bluefish, Atlantic mackeral, butterfish, and bluefin tuna. Species which move southward from the Gulf of Maine along the Mid-Atlantic Bight include; the Atlantic herring, Atlantic cod, and pollock. The major factor involved in these movements is temperature. Fish have definite preferences for certain temperatures. Fish which remain in the Gulf of Maine year around (eelpout, sculpin, little skate, and winter flounder) move into deeper waters during the colder months, then move back into shallow water in the spring when water temperatures increase.

Fisheries investigations offshore (20 to 200 meters) have indicated that a total of 110 species normally can be found in the North Atlantic Region. The dominant species off western Nova Scotia include haddock, Atlantic cod, pollock and spiny dogfish. A total of 67 species were caught in the Gulf of Maine. The dominant species were redfish, haddock, spiny dogfish, thorny skate, Atlantic cod, silver hake, pollock and American plaice. Of the 68 species taken on Georges Bank, the following were dominant; Atlantic cod, yellowtail flounder, winter skate, little skate, and eelpout. The principal species on the Mid-Atlantic Bight include: spiny dogfish, yellowtail flounder, red hake, silver hake, little skate and eelpout (TRIGOM, 1974).

Marine Mammals

Whales, dolphins and porpoises constitute the majority of marine mammals which have been reported along the South Atlantic Region. Occasionally manatees have been observed in the southern coastal waters of this region. No whales or porpoises are taken along the Atlantic as a result of the U. S. Marine Mammal Protection Act of 1972, although the Atlantic bottlenosed dolphin and the Atlantic spotted dolphin have been captured for display and research. Most data on nearshore sightings of marine mammals indicate the presence of stranded, sick or injured animals and thus give an erroneous indication of species distributions and populations. Thirty-six species of marine mammals have been reported in the Central Atlantic region. A small population of grey seals hauls out near Nantucket. Other seals and the manatee have been rarely sighted in the Mid-Atlantic region. Whales are regularly sighted in the Mid-Atlantic region as are propoises and dolphins.

The harbor seal is a resident in the North Atlantic Region year around. The grey seal is a relatively common transient in this region. Eight species of cetaceans (whales and porpoises) have been regularly reported in the Gulf of Maine (TRIGOM, 1974). Another eight species have rarely been reported and are considered strays. In general little is known about the occurrences and life histories of cetaceans along the entire Atlantic Coast.

(5) Birds

Pelagic birds normally found along the South Atlantic Region include: petrels, shearwaters, gannets, phalaropes, jeagers and terns. The birds which migrate through the area annually are part of two groups. The first group moves southward in the fall (gannet, northern and red phalarope, skuas, and jeagars). The second group of migratory birds includes the Wilson's storm petrel which breeds on islands in the South Atlantic and migrate to the North Atlantic (VIMS, 1974). Wilson's storm petrels and shearwaters have been observed in flocks exceeding 10,000 along the South Atlantic Region. Oceanic birds reported in the Central and North Atlantic Regions include the fulmar, shearwaters, petrels, gannets, phalaropes, jeagers, kittiwakes, auk, murres, and the dovekie.

Marine birds feed on fish, plankton, and detritus. Fish-eating birds return nutrients from the water back to shore and are instrumental in recycling nutrients within the surface layer. Bird feces contain more readily usable forms of nutrients than the food organisms. Sea birds also utilize the shoreline for breeding and the raising of their young.

(6) Unique Environments

Four offshore types of unique bottom assemblages have been described. These are the calico scallop beds, coral outcroppings, relic reef deposits, and "black rock reefs". Two calico scallop beds have been identified off Cape Canaveral and in Raleigh Bay (VIMS, 1974). A total of 112 species were identified from one dredge in these beds. The dominant species were the calico scallop and several polychaetes.

Coral outcroppings have been investigated in Onslow Bay, North Carolina. These areas are utilized as food sources by commercial demersal fishes. Eighty-nine species of polychaetes and 74 species of molluscs are associated with these coral structures. The order of dominance of species varies from one outcropping to another.

A large (80 nautical mile long) reef, formed by ancient Lithothanmion deposits has been discovered at the edge of the shelf off North Carolina (VIMS, 1974). One hundred and seventy species from 11 phyla have been identified from this reef. Of these, 62 species were molluscs, 48 arthopods, and 17 annelids. The dominant organisms on the upper reef were the pelecypod Glycymeris and epifaunal echinoids, gorgonians, hydroids, and bryozoans. The dominant organisms on the lower reef include the gastropod Polystira and the crab Acanthocarpus (VIMS, 1974).

Rock outcroppings referred to as "black rock reefs" have been identified off the coast of North Carolina and northward (VIMS, 1974 and URI, 1974). These outcrops consist primarily of Trent marl (fossil remains of the pelecypod Venus gardneri). Over 300 species which are normally associated with these outcroppings have been identified. Tube building polychaetes and a sessile snail (Vermiculari spirota) are the major species responsible for present reef building. Sessile clams and the boring clams (Soxicava rugosa and Lithophaga bisulcota) are the most conspicuous organisms in samples of these structures.

Unique benthic communities occur in the nine submarine canyons located in the Central Atlantic region. These canyons are characterized by straight V-shaped valleys with unconsolidated motile sediments in the valley floor. Rowe (1971) described a sea cucumber (Ophiomusuim bymani) which characterizes the Hatteras Canyon.

e. Natural Phenomena Unique to an Area with Potential to Cause or Contribute to Environmental Impacts of Proposed Action (Atlantic)

(1) Winds

The incidents of winds along the Atlantic coastline have been described in the section on climatology. The most severe wind conditions occur during the passage of a hurricane system through the area. Tetra Tech, Inc. (1973) estimated the annual probability of sustained winds exceeding 80 knots to be 0.1; in excess of 100 knots to be 0.05; and 120 knots to be 0.01. Sustained winds in excess of 80 knots represent hazardous operation conditions aboard rigs and supply vessels. Wind generated or swells resulting from severe wind conditions accentuate the hazard.

(2) Waves

Wind generated waves have been briefly described in the physical oceanography section. The occurrence of waves in excess of 50 feet constitutes a significant hazard to offshore operations. The reporting of a wave in excess of 112 feet by the USS Ramapo (as described in the section on waves) points out the potential significance of these occasional waves.

No damaging tsunamis (seismic sea waves) have been reported along the Atlantic coast. However, storm surges have caused extensive damage along low lying coastal areas of the Atlantic coast (see description in the section on physical oceanography).

(3) Icing

Ice formation, may occur in the northern portions of Georges Banks, especially during the month of February.

(4) Reduced Visibility

The incidence of reduced visibility has been described in the meteorology section.

(5) Geologic Conditions

Glaciated areas of the north Atlantic shelf are characterized by irregular topography and locally-thick accumulations of unconsolidated bottom sediment. Linear sand swales and ridges occur along virtually the entire East Coast inner shelf, and have been known to migrate over distances of several tens of meters during severe storm activity. Portions of the extensive barrier island system extending southward from Long Island to the Carolinas are also vulnerable to significant morphologic change.

No damaging tsunamis (seismic sea waves) have been reported along the Atlantic coast. However, storm surges have caused extensive damage along low lying coastal areas of the Atlantic coast (see description in the section on physical oceanography).

(3) Icing

Ice formation, may occur in the northern portions of Georges Banks, especially during the month of February.

(4) Reduced Visibility

The incidence of reduced visibility has been described in the meteorology section.

(5) Geologic Conditions

Glaciated areas of the north Atlantic shelf are characterized by irregular topography and locally-thick accumulations of unconsolidated bottom sediment. Linear sand swales and ridges occur along virtually the entire East Coast inner shelf, and have been known to migrate over distances of several tens of meters during severe storm activity. Portions of the extensive barrier island system extending southward from Long Island to the Carolinas are also vulnerable to significant morphologic change.

2. Gulf of Mexico Region

a. Geology

The Gulf of Mexico continental margin consists of two different geologic provinces--an eastern region of shallow carbonate banks and relatively simple structure, and a western region of primarily land-derived sediments and complex structural regime involving extensive faulting and salt mobilization.

(1) Eastern Gulf of Mexico OCS

(a) General

The continental margin of the eastern Gulf of Mexico represents part of a broad area of shallow-water carbonate and evaporate accumulation that includes also the Yucatan and Bahama platforms to the west and east, respectively.

The broad continental shelf off Florida, known as the West Florida Shelf, varies in width from less than 100 km in the north to more than 250 km in the southwest (Fig.22). Reef structure and relict shoreline features impart minor topographic relief to the relatively flat shelf. An extensive reef-type complex called Florida Middle Ground covers an area of more than 750 km^2 on the outer shelf northwest of Tampa with topographic relief of up to 18 meters (Bergantino, 1971).

The West Florida Escaprment lies at the base of the continental slope and forms the western boundary of the continental margin off

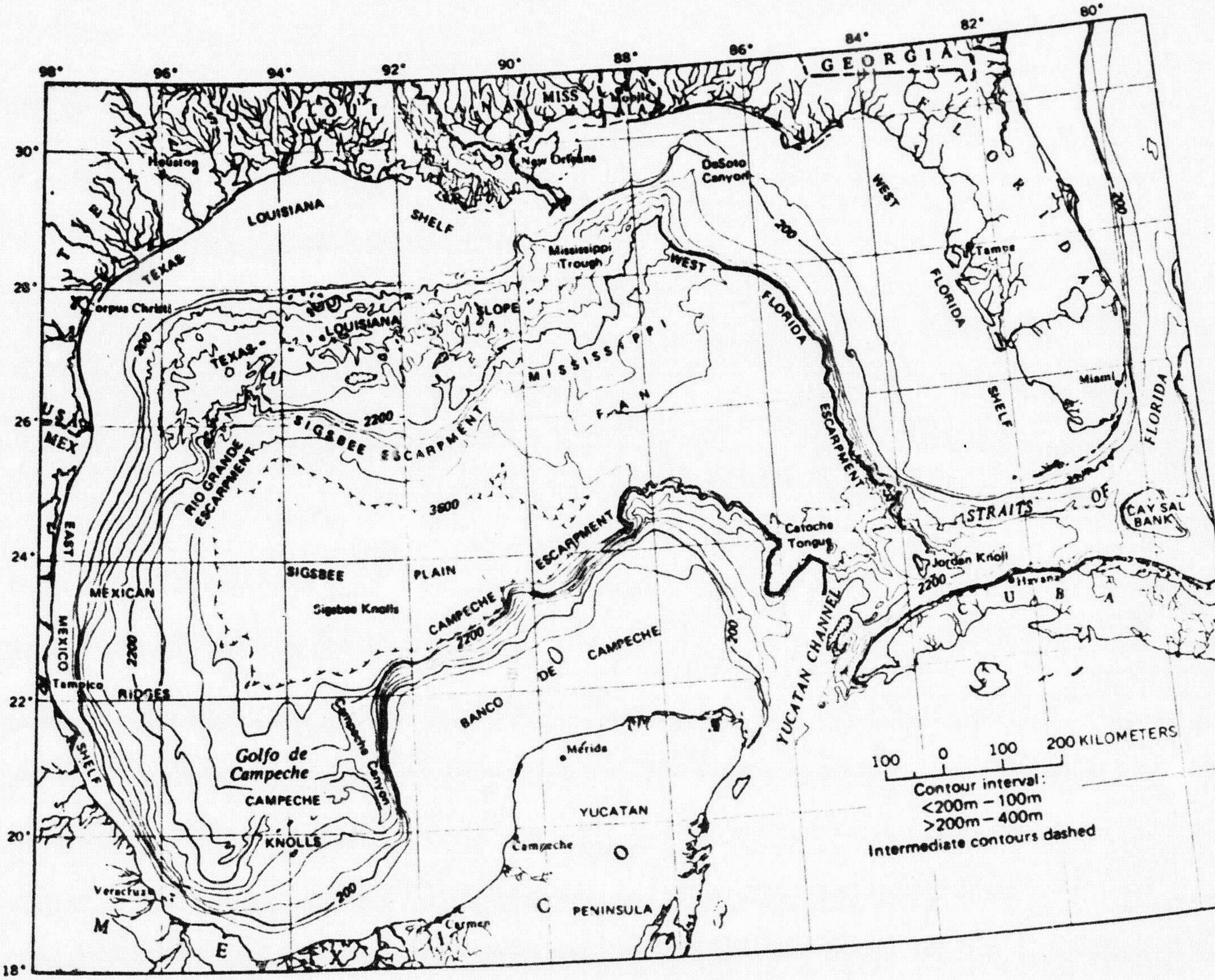

98°
96°
94°
92°
90°
88°
86°
84°
82°
80°
30°
28°
26°
24°
22°
20°
18°
GEORGIA
MISS
ALA
Mobile
Houston
New Orleans
DeSoto Canyon
LOUISIANA
SHELF
TEXAS
Corpus Christi
Mississippi Trough
WEST FLORIDA
WEST FLORIDA SHELF
FLORIDA
Tampa
Miami
TEXAS-LOUISIANA SLOPE
MISSISSIPPI FAN
SIGSBEE ESCARPMENT
2200
200
3600
RIO GRANDE ESCARPMENT
FLORIDA ESCARPMENT
USA
MEX
STRAITS OF FLORIDA
CAY SAL BANK
Catoche Tongue
Jordan Knoll
Havana
CUBA
SIGSBEE PLAIN
Sigsbee Knolls
CAMPECHE ESCARPMENT
EAST MEXICAN SHELF
MEXICAN RIDGES
Tampico
BANCO DE CAMPECHE
YUCATAN CHANNEL
Golfo de Campeche
Campeche Canyon
CAMPECHE KNOLLS
Mérida
YUCATAN PENINSULA
Campeche
Carmen
Veracruz
MEXICO
100 0 100 200 KILOMETERS
Contour interval:
<200m – 100m
>200m – 400m
Intermediate contours dashed

FIGURE 22 -Bathymetric map of the Gulf of Mexico showing major physiographic and structural features. Bathymetry adapted from Uchupi (1967). (from Garrison and Martin, 1973).

Florida. To the south, the eastern Gulf continental margin is bordered by the Straits of Florida, while in the north, the boundary consists of an area of lithologic and structural transition joining the eastern Gulf carbonate province to the western Gulf clastic province. The DeSoto Canyon, a submarine feature within this transition zone, is usually taken as the physiographic boundary between the eastern and western Gulf geologic provinces.

Subsurface Geology

Geophysical surveying and onshore drill data have revealed a southward-thickening section of Mesozoic-Cenozoic shallow-water carbonate and evaporite strata beneath the Florida Platform (Fig. 23). The thick southern sequence accumulated in a subsiding depositional trough (South Florida Embayment) which extended over much of the southern Florida shelf and eastward to the Bahamas. In the more slowly-subsiding northern area of the peninsula, shallow marine deposits are mixed with non-marine clastic material derived from emergent areas further north.

The major positive subsurface structural feature in the region is the NW-SE trending Peninsula arch, which existed as a topographic high during Early Cretaceous and early Late Cretaceous time. An auxilliary structure, the Ocala uplift, extends from the Peninsula Arch towards the Gulf (Fig. 24

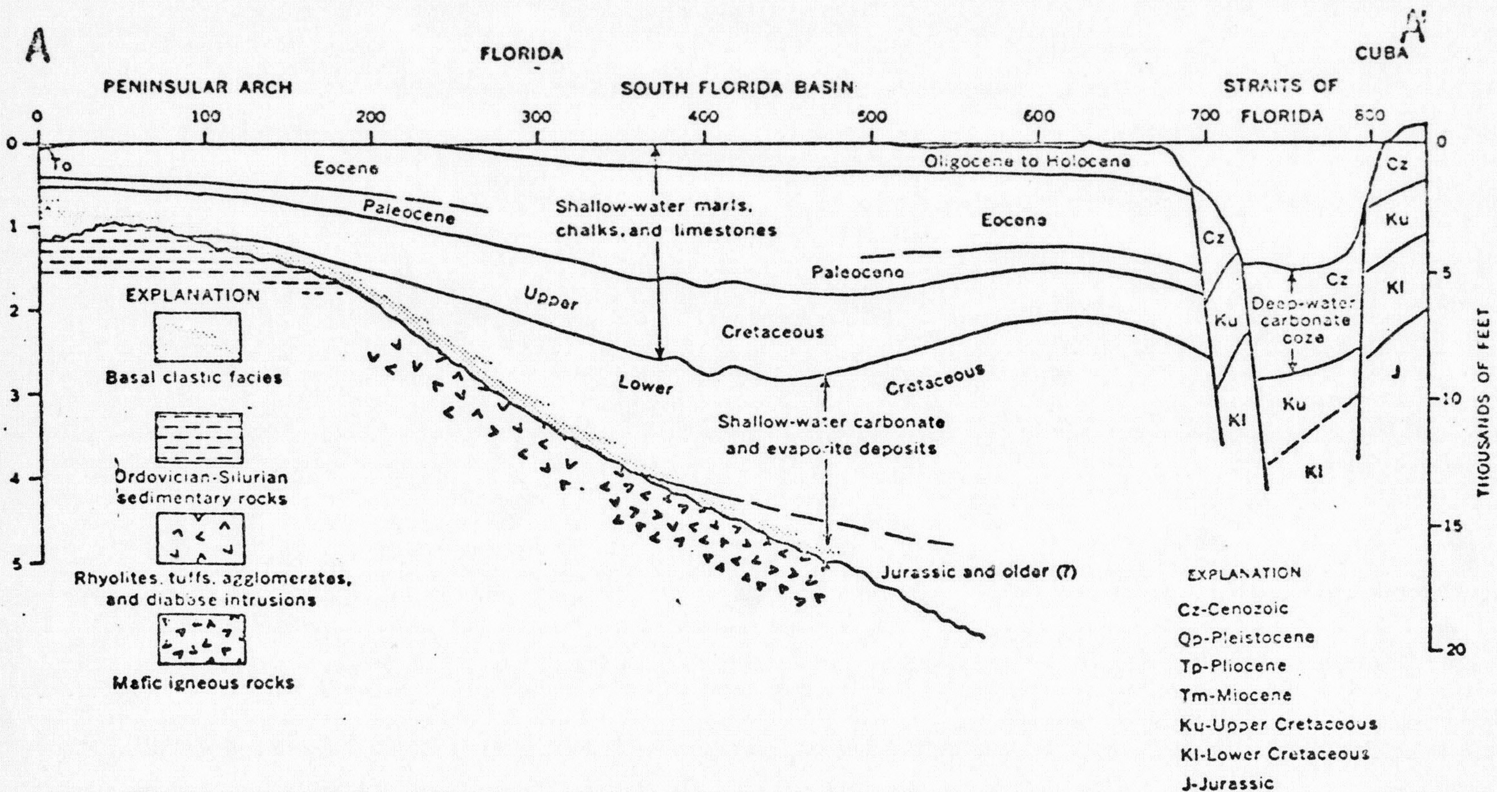
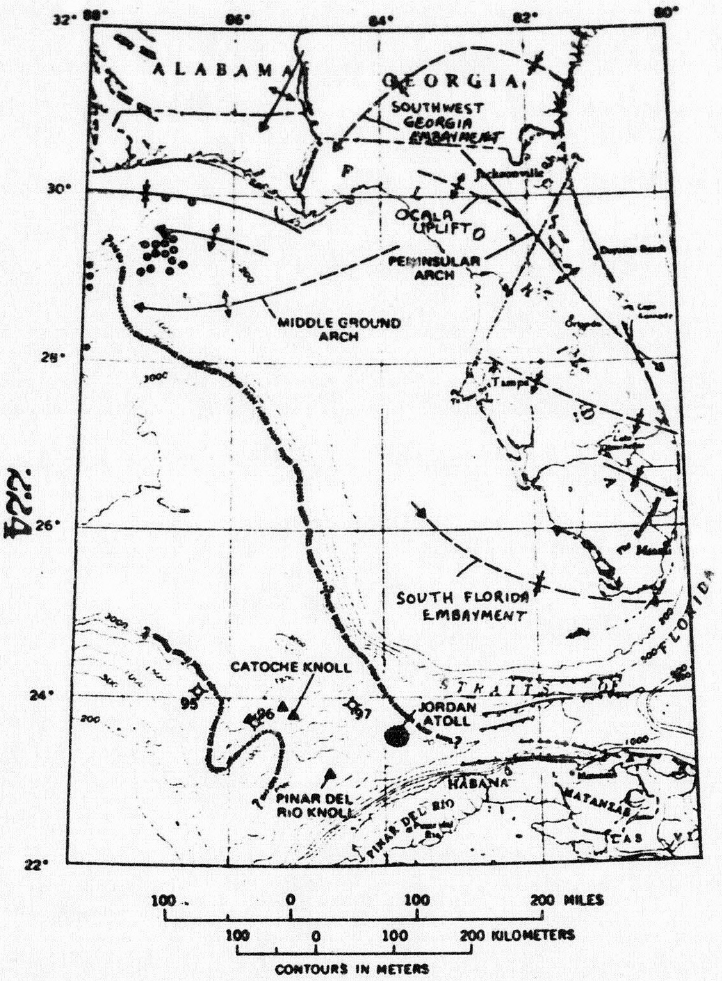

A
FLORIDA
A'
CUBA
PENINSULAR ARCH
SOUTH FLORIDA BASIN
STRAITS OF FLORIDA
0
100
200
300
400
500
600
700
800
0
1
2
3
4
5
0
5
10
15
20
THOUSANDS OF FEET
To
Eocene
Oligocene to Holocene
Paleocene
Shallow-water marls, chalks, and limestones
Eocene
Paleocene
Upper
Cretaceous
Lower
Cretaceous
Shallow-water carbonate and evaporite deposits
Jurassic and older (?)
Cz
Ku
Kl
Cz
Deep-water carbonate ooze
Ku
Kl
Cz
Ku
Kl
J
EXPLANATION
Basal clastic facies
Ordovician-Silurian sedimentary rocks
Rhyolites, tuffs, agglomerates, and diabase intrusions
Mafic igneous rocks
EXPLANATION
Cz-Cenozoic
Qp-Pleistocene
Tp-Pliocene
Tm-Miocene
Ku-Upper Cretaceous
Kl-Lower Cretaceous
J-Jurassic

Figure 23 Schematic N-S cross section of eastern Gulf of Mexico (from Martin and Case, in press, A.A.P.G.)


32°
88°
86°
84°
82°
80°
30°
28°
26°
24°
22°
ALABAMA
GEORGIA
SOUTHWEST GEORGIA EMBAYMENT
Jacksonville
F
L
OCALA UPLIFT
PENINSULAR ARCH
Daytona Beach
MIDDLE GROUND ARCH
Tampa
Miami
SOUTH FLORIDA EMBAYMENT
CATOCHE KNOLL
95
96
97
JORDAN ATOLL
STRAITS OF FLORIDA
HABANA
MATANZAS
PINAR DEL RIO KNOLL
PINAR DEL RIO
3000
2000
1000
200
100 0 100 200 MILES
100 0 100 200 KILOMETERS
CONTOURS IN METERS

EXPLANATION

ANTICLINAL AXIS – Axis of open fold or arch showing direction of plunge; mainly basement rocks, dashed where inferred

SYNCLINAL AXIS – Axis of large fold or embayment showing direction of plunge; many of these involve basement rocks, dashed where inferred

MONOCLINE

THRUST FAULT – Sawteeth on overthrust side

NORMAL FAULT – Hachures on downthrown side

CONCEALED FAULT – Involves basement surface only

BARRIER REEF – Approximate trend of Lower Cretaceous reef revealed by seismic-reflection profiles and bottom samples in eastern Gulf of Mexico, and by geophysical data and drilling in Mexico

SALT DOMES – Diapiric structures known or inferred to be formed by evaporites. Dot indicates domes in which salt or caprock has been reached by drilling; open circle denotes diapirs revealed by seismic-reflection profiling. The apparent linear distribution in places reflects the ship's track

IGNEOUS INTRUSION – Pluglike mass interpreted from geophysical data to be of igneous origin

3◇ **DRILL HOLE** – Location and number of JOIDES Deep Sea Drilling Project site

Figure 24. Principal structural elements and trends of the eastern Gulf of Mexico and adjacent coastal plain (after Garrison and Martin, 1973).

The Southwest Georgia Embayment, extends across the northeastern Florida Panhandle into southern Georgia and Alabama. While onshore wells in this area have revealed a Cretaceous-Miocene sedimentary rock section almost 9000 feet thick (Rainwater, 1971), Maher (1971) estimates the thickness of the offshore section may exceed 15,000 feet.

Bottom Sediments

The unconsolidated sediment cover of the eastern Gulf continental shelf areas is discontinuous and thin, representing in large part, relict deposits which date from the last major marine trangression (rise in sea level) that occurred during late Wisconsin time. Sediments of the west Florida shelf grade seaward from relict, near-shore quartz sands through zones dominated by shells and shall fragments, algal, peletoid, and oolitic carbonate sands to biogenic silts and oozes on the outer shelf and slope (Gould and Stewart, 1955). Shelf sands along the Mississippi-Alabama coastline extend up to 50 miles (80 km) offshore, and to water depths exceeding 55 meters (Brooks, 1973).

(b) Hydrocarbon Potential

Since few wells have been drilled in the eastern Gulf of Mexico, little is known of the actual hydrocarbon potential of this area. Some measure may be gained through inference from onshore geology, and producing trends and interpretion of offshore seismic data, although these estimates are highly speculative.

There has been significant production from the onshore Mississippi-Alabama-Florida area. Numerous fields have been in operation since 1939. At least 133 fields have been discovered with Mesozoic production. In addition, there are 23 Mesozoic fields in Alabama and three in the northern Florida Panhandle. Production is mostly centered in the eastward extension of the Mississippi Salt Basin, a structure that contains shallow salt domes (as shallow as 410 feet) and has a large potential for hydrocarbon production (Braunstein, 1958). Alabama fields are smaller than those in Mississippi, but are also located on the margin of the Mississippi Salt Basin. The most productive zones in these states are the lower and upper Cretaceous formations including the Tuscaloosa, Eutaw, Paluxy, and Glen Rose formations, all of which are sands (Rainwater, 1970, Paine and Meyerhoff, 1970; and Braunstein, 1958). Production in Florida is limited to two areas, although several hundred wells have been drilled. The Jay field, located in Santa Rosa County in the Panhandle was discovered in 1970, and is producing from the Jurassic Smackover formation which is a very prolific oil-producing limestone at onshore locations.

Four fields are active in South Florida, the largest of which is the Sunniland field. All of these fields are in the lower Cretaceous Sunniland limestone, and are part of the thick shale and carbonate sequence of the South Florida Embayment. There is some promise for large fields in this trend which is continuous onto the continental shelf of West Florida. Stratigraphic and reef traps are the most likely types of oil reservoirs, although some structural traps may be present and are potential producers.

Initial exploratory drilling of the once highly-prospective Destin Anticline has been disappointing. One deep-Jurassic and six Cretaceous test holes have proven non-commercial. Should current tests in other eastern Gulf areas fail also to reveal commercial hydrocarbon quantities, further exploratory activity in the region may be curtailed, as operators turn to better known areas in the central Gulf or attractive frontier acreage elsewhere.

Farther south on the West Florida shelf, there is abundant evidence of reefs of probable lower Cretaceous age. There is a strong possibility that production could occur from these reef structures and from the seaward continuations of the thick sequence of strata in the South Florida Embayment.

(c) Geologic Hazards

The Eastern Gulf shelf is a seismically stable geologic area, having shown little earthquake activity for at least the last two hundred years.

Parts of the West Florida shelf are characterized by a submerged karst [1] topography. In addition, cavernous limestone strata have been identified at the base of the Eocene. While irregular bottom topography can be delineated prior to rig placement, a potential lost circulation zone may not be recognizable prior to drilling. The problem of lost circulation has been encountered many times during drilling operations in other geographic areas, however, so that adequate procedures have been developed to safely handle its occurrence.

Many wells penetrating Mesozoic rocks in Mississippi have encountered abnormally high formation pressures. The extent of these Mesozoic geopressures in other onshore and offshore areas is not known, although they were not encountered in Smackover (Jurassic) strata during development of the Jay field on the Florida Peninsula.

(2) Central and Western Gulf of Mexico OCS

(a) General

Much of the lithologic and structural character of the Western Gulf of Mexico can be related to the thick

---

1/ Carbonate rocks are prone to dissolution by circulating water, e.g., rivers or subsurface groundwater, so that geographic areas characterized by sufficient rainfall, extensive limestone strata and active subsurface runoff, commonly develop a system of underground channels, caverns and nearsurface sinkholes. The term, Karst topography, is derived from such a region--the Karst district on the eastern coast of the Adriatic Sea.

clastic sedimentary sequence which accumulated in the Gulf Coast Geosyncline during the Cenozoic Era and the extensive Jurassic evaporite deposits that underlie much of this Cenozoic section.

Gulf Coast Geosyncline (Gulf Coast Basin)

The Gulf Coast Geosyncline is a broad depositional trough that extends over much of the western Gulf continental margin and adjacent land areas. Onshore, to the north and west, the structural basin and its sedimentary deposits form the emergent Gulf Coastal Plain. The continental shelf is the underwater extension of this generally smooth, gently-dipping coastal plain. The shelf offshore Texas and Louisiana ranges in width from 60 miles (97 km) on the west to 160 miles (257 km) off the Texas-Louisiana border. The continental slope of the northwestern Gulf marks the seaward extent or growth margin of the Geosyncline.

In existence since at least the Mesozoic Era, the Gulf Coast Basin has received Cenozoic sedimentary deposits which amount to more than 50,000 feet in total thickness. These Cenozoic deposits are predominantly clastics (sands, silts, and clays), derived from land areas to the north and west and carried into the basin by major rivers draining into the Gulf of Mexico. The great majority of these deposits represent the coalescing, overlapping deltas of rivers which repeatedly shifted their courses throughout the Cenozoic. Near the seaward margins of these ancient deltas, deltaic deposits grade into, and interfinger with marine shales and clays. Deposition in the basin has been almost continuous throughout the Cenozoic era, with slow, general subsidence of the basin floor keeping approximate pace with the rate at which the sediments accumulated. The result has been partial filling of the Gulf Coast basin with a thick prograding sedimentary rock wedge which pinches out updip towards the margins of the basin and thickens seaward.

Structure

Offshore Louisiana, in spite of the subsidence which has taken place in the Gulf Coast Basin beneath it, it a stable area of relatively simple tectonics. Its most prominent structural anomalies are salt domes and a series of regional, down-to-the-Gulf faults which have materially affected sedimentation across them. Less common are deep-seated, low-relief uplifts and shale domes or ridges. These structural features are related to the presence of an underlying salt basin and the Cenozoic sedimentary wedge which has gradually advanced seaward across it.

Beneath the north-central and northwestern Gulf, the thick layer of salt laid down over 100 million years ago has been slowly deformed and mobilized by the excessive weight of prograding Cenozoic sediments. In areas of sufficient overburden, the lower density of the salt has caused it to rise buoyantly, upwarping and, in many cases, penetrating the overlying strata.

Rock units commonly show greater thicknesses on the downthrown sides of these faults, and the name "growth faults" is often applied to them (and to other, more localized faults which show the same pattern of thickening in rock units on their downthrown sides). Going seawards, each successive fault is progressively younger than the preceding one. Distributional characteristics like these, plus the general shape and form of these features, suggest their probable origin--as gravity slumps (underwater landslides) which have occurred periodically and repeatedly at the seaward (continental slope) edge of the growing sedimentary wedge.

Fine-grained sediments of the Mississippi Fan dominate the north-central Gulf region. This thick accumulation of primarily Quaternary alluvium extends over a 160,000 square km. area including parts of the shelf, slope, rise and abyssal floor.

In western areas of the Gulf, surface sediments are generally thin, thickening only near the mouth of rivers. The Holocene sediment cover is unconsolidated and discontinuous over much of the Texas shelf. These deposits are primarily silty clays with sand zones nearshore, while some sizable areas of shell and silt occur also, particularly off Padre Island. Tropical storms in the western Gulf have historically redistributed large volumes of unconsolidated bottom sediments, and have altered the morphology of the extensive barrier island system that parallels the Texas coast.

(b) Hydrocarbon Potential

Since natural production of oil and gas frequently occurs along the continental shelf-slope break, the progradation of the north-central Gulf depositional regime has resulted in the migration of this hydrocarbon production zone seaward, developing a series of progressively younger bands or trends. Figure 25 shows the late Tertiary and Quaternary production trends which underlie the Western Gulf OCS.

The most prolific offshore production comes from the Miocene of the eastern Louisiana OCS. This area, as currently defined, has more oil than the remainder of the Texas-Louisiana offshore area. The next most productive trend is the Pliocene trend of the central Louisiana OCS which produces about 50%-50% oil and gas. Farther to the west this trend probably dies out. The Miocene of western Louisiana is the third most productive trend producing mostly gas, and the Pleistocene of western Louisiana ranks fourth.

The prospective horizons of the upper slope of offshore Texas should consist of a veneer of Miocene and Pliocene with thicker intervals of Pleistocene. The Pleistocene sediments are considered the most

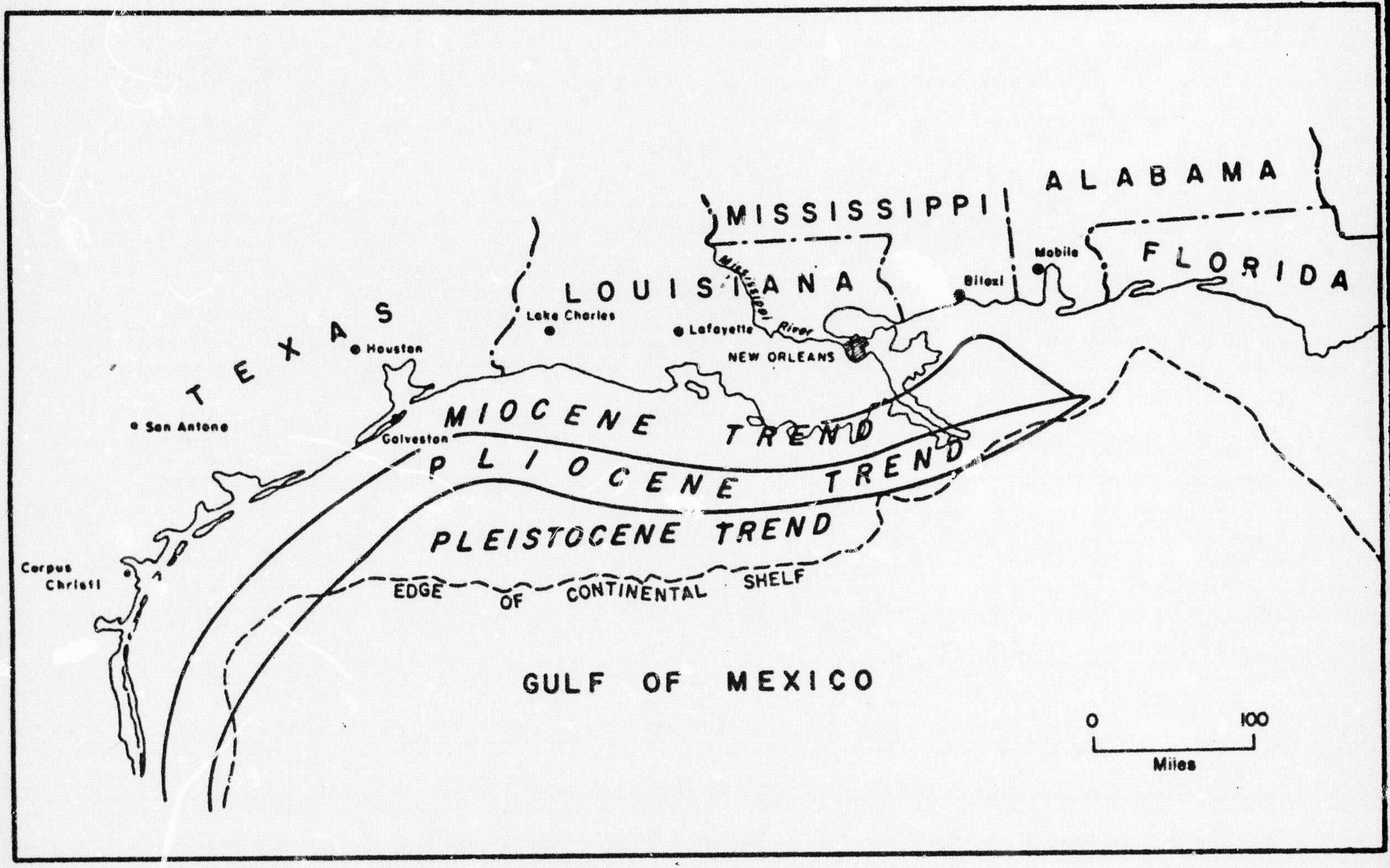

ALABAMA
MISSISSIPPI
FLORIDA
LOUISIANA
Mobile
Biloxi
Mississippi River
TEXAS
Lake Charles
Lafayette
Houston
NEW ORLEANS
San Antone
Galveston
MIOCENE TREND
PLIOCENE TREND
PLEISTOCENE TREND
Corpus Christi
EDGE OF CONTINENTAL SHELF
GULF OF MEXICO
0
100
Miles

Figure 25 Productive "trends", offshore Louisiana and Texas.

prospective reservoir beds and the thickness of these deposits on the slope is variable but at least 10,000 feet of sediments, predominantly clay, is estimated to be present in several synclines on the continental slope.

(c) Geologic Hazards

The major potential geologic hazard to the north-central Gulf OCS concerns the instability of recent bottom sediments in the area of the Mississippi River delta. The problem of foundation failure is not a new one to most operators in deltas areas around the world, some of whom have experienced a variety of mishaps ranging from pipeline ruptures to the total loss of costly production platforms. Intensive investigations of a number of such mishaps have been conducted by the major oil companies and the Government. Some of the pioneering work in this field by Shell Oil Company suggests that in some cases fluctuating pressures within the upper 100 feet of sediment caused by storm waves may trigger a sediment failure. Other investigations conducted at Louisiana State University indicate the content of dissolved and undissolved gases in sediments may play an important role in their instability.

High resolution seismic reflection and side-scan sonar data can reveal surface and subsurface detail to a sub-bottom depth of about 1,000 feet. Potential surface and shallow geologic hazards such as mud waves, slumps, and shallow faults can be identified prior to drilling or rig placement.

Recent engineering investigations concerning platform design and rig placement in areas with unstable bottom sediments suggest that potential damage to these structures can be minimized by increasing both the strength of support members and the depth of sub-bottom penetration of these members; pilings would be driven into more competant strata below the zone of instability.

The USGS, with the cooperation of the Coastal Studies Institute of Louisiana State University, is currently assessing the areal extent of sediment instability in the Delta region.

Additional hazards in the Western Gulf area involve the presence of shallow (1000') gas deposits offshore Texas and their related blowout potential, and shifting sediments along nearshore areas off Texas in response to storm activity.

b. Climate

(1) General Climatology and Seasonal Weather Patterns

The climate of the Gulf of Mexico Region is broadly determined by the huge continental land mass lying to the north and west, the subtropical latitude, the influence of the persistent Atlantic high-pressure system (Bermuda-Azores), and the warm waters of the Gulf itself.

From March through September the eastern Gulf lies under the western portion of the well-developed Bermuda high-pressure cell. Around this cell winds move in a clockwise spiral. Due to this influence winds in the Gulf Region are south to southeasterly much of the time with a tropical maritime (Tm) air mass dominating the region almost completely. Air mass thundershower activity increases during the day with the greatest activity in the afternoon. Summer rainfall is generally associated with southerly winds. When westerly to northerly winds occur in summer, periods of hotter and drier weather interrupt the moist semi-tropical climate of this coastal region.

In winter the area is subjected alternately to maritime tropical and polar continental air (Pc) masses in periods of varying length. This region is usually south of the average track of winter cyclones but occasionally one will move this far south. Westerly systems at times make their influence felt as cold fronts from the northwest push southward into the Gulf of Mexico. The cold air behind these fronts, though modified by the southward journey, brings sudden and occasionally large drops in the temperature. The Gulf of Mexico, with its relatively warm waters, introduces retarding and modifying effects upon cold fronts. As the invading cold air mass pushes out over the Gulf it moves against the strong flow of maritime tropical air in the opposite direction causing the front to become quasi-stationary. At these times the Northern Gulf area becomes a favored region for cyclogenesis (formation of circular wind movement around centers of atmospheric low pressure). When waves develop on the front they are usually associated with an eastward-moving upper air trough. The principal track of the associated low center parallel the Gulf Coast or moves inland producing persistent low stratus cloud ceilings and rain in the Northern Gulf area. These conditions usually persist ahead of the low centers. The colder air masses in winter tend to gradually lower the sea surface temperature offshore. This plays an important role in the formation of advection-radiation fogs in coastal areas from November-March and the formation of dense sea fog over the relatively cold water surface. The direction of flow of warm air at the surface near the coast determines where the fog will form. Snow seldom occurs this far south in winter. With the arrival of spring, the occurrence of fog, rain and low ceilings becomes less frequent.

Two remaining air mass types occasionally reach the Gulf, with decreasing frequencies toward the southern coasts. During the late fall and during the spring polar maritime (Pm) air may push into the Gulf where it is rapidly modified. Arctic (A) air mass invasions are normally confined to the months of January and February. Although these air masses are considerably modified by the time they reach the Gulf, sub-freezing temperatures may at times be carried over land to near the extreme southern limits of the area.

(2) Sky Cover and Visibility

Cloudiness. Along the Gulf Coast average annual cloud cover varies between 50 and 60 percent with relatively small seasonal variation. October is generally the clearest month and December through March the cloudiest. The nature of the cloudiness varies with the season. In winter the Gulf Coast has occasional gray, overcast days but in summer these are rare.

Fog. Warm, moist Gulf air blowing slowly over chilled land surfaces brings about the formation of fog at the ground. From November through April, fog is encountered occasionally at points throughout the Gulf coast region. It is most frequent in the vicinity of harbor entrances and over land areas extending into the Gulf, such as Cape San Blas. Fog forms with southerly winds and dissipates during northerly winds.

Fog is relatively infrequent at most Florida coastal points, with the exception of Tampa in the winter. There is a greater frequency along the Alabama and Louisiana coasts and the Texas coastal bend, with lesser amounts on the southwest Texas coast. The heavist occurrence of fog is usually in the early morning hours.

(3) Surface Wind Patterns

The Azores-Bermuda atmospheric high pressure cell dominates the circulation over the Gulf, particularly during the spring and summer months. In later summer there is a general northward shift of the circulation and the Gulf comes under the more direct influence of the equatorial low pressure belt. During the relatively constant summer conditions, the southerly position of the Azores-Bermuda cell brings about predominance of southeasterly winds. The winds tend to become more southerly in the northern part of the Gulf. During the winter, winds usually blow from easterly directions with fewer southerlies but more northerlies. Winds from west and southwest are rare anytime during the year.

Near the Gulf Coast winds are more variable than over the open waters of the Gulf because the coastal winds fall more directly under the influence of the moving cyclonic storms that are characteristic of the continent.

(4) Air Temperatures

Average temperatures at coastal locations vary with latitude and exposure, and in winter depend, in addition, on the frequency and intensity of penetration by polar air masses from the north. These incursions, when they bring strong northerly winds to the Gulf, are called "nothers" and may occur some 15 to 20 times between November and March.

Air temperatures over the open Gulf exhibit narrower limits of variation both on a daily and seasonal basis (Figure 26). In July, average temperature over the center of the Gulf is about 85°F and gradually increases coastward to within 10°F of temperatures recorded at coastal localities. In January, average air temperatures over the Gulf are highest in the southeast, near Cuba and the Yucatan Peninsula, and decrease toward the north. East of Brownsville/ Corpus Christi, January air temperatures over the open Gulf average about 65°F; at the Galveston-Mississippi Delta latitude, the temperature is about 60°F.

(5) Precipitation

Average annual precipitation along the Gulf coast increases from approximately 27 inches at Brownsville to over 40 inches at Galveston, 54 inches at New Orleans, and reaches a maximum in the vicinity of Mobile, which receives over 68 inches. Peninsula Florida generally receives over 50 inches of rainfall

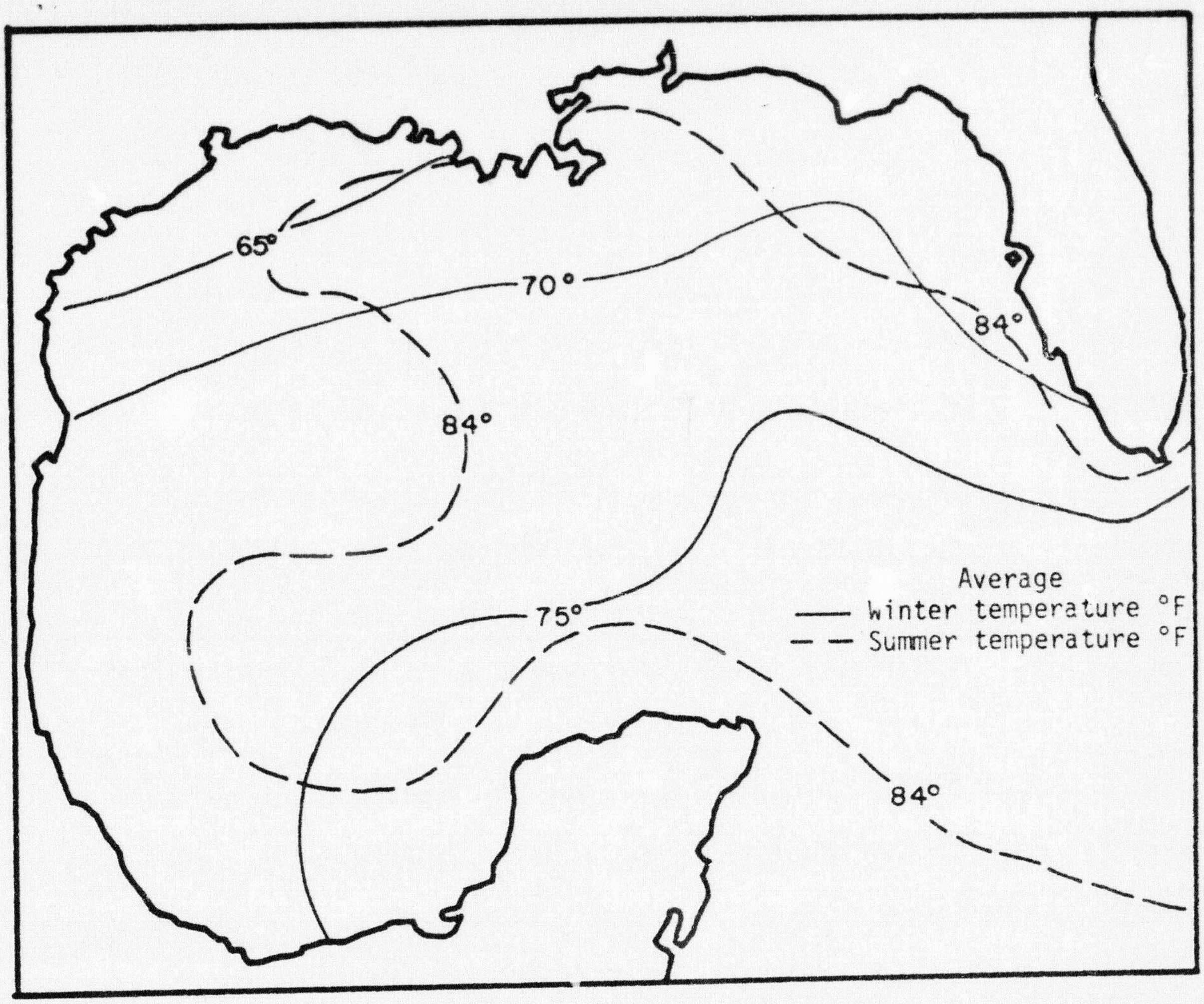

65°
70°
84°
84°
75°
84°
Average
— Winter temperature °F
– – Summer temperature °F

Figure 26 Average summer and winter surface isotherms in °F for the Gulf of Mexico (Leipper, 1954).

per year; values decline off the tip of Florida where Key West receives 40 inches.

Along the central Gulf precipitation is frequent and abundant throughout the year. At New Orleans, October is the only month with a precipitation average less than 3 inches. July, the wettest month, receives just under 7 inches. Stations along the entire Gulf coast record the highest precipitation values during the warmer months of the year. The month of maximum rainfall for most locations is July; however, at the extreme ends of the Gulf coast, Key West and Brownsville record maximums in September.

These warmer months usually have convective cloud systems which produce showers and thunderstorms; however, thunderstorms of this type rarely cause any damage or have attendant hail. Tornadoes and waterspouts are also extremely rare in this area (Brower, et al., 1972).

Heavy rainfall amounts associated with tropical cyclones account for the high monthly average in September. In October, 1937, a record fall of 25 inches was recorded at New Orleans, approximately eight times the normal amount for that month.

(6) Severe Storms

Tropical Cyclones

The largest and most destructive storms affecting the Gulf of Mexico and adjacent coastal zone are tropical cyclones. Tropical cyclones are low pressure storm systems that have their origin over the warm tropical waters of the central Atlantic Ocean, Caribbean Sea, or southeastern Gulf of Mexico. They, by definition, must have winds in excess of 34 knots, and if the winds exceed 64 knots they are considered hurricanes. Tropical cyclones occur most frequently between June and late October (Brower et al., 1972) and there is a relatively high probability that tropical cyclones will cause damage in the Gulf of Mexico each year. Statistics for hurricanes and tropical cyclones are often lumped together since it is often difficult, especially in the older records, to determine the storm intensity while at sea. The probability of a tropical cyclone or hurricane influencing the north-central Gulf Coast during any given year is 1 in 6. The earliest and latest occurrence of tropical cyclones for the period 1886-1970 is from the months of May through November.

Most hurricanes and tropical cyclones influencing the Gulf of Mexico form in the eastern Caribbean or the central Atlantic Ocean and there is adequate warning, often as long as several days, of the inpending danger. There is no preferred approaching route of hurricane tracks although early season cyclones approach generally from the southeast while later ones are more out of the south.

Damage from hurricanes results from high winds and, particularly in the coastal areas, the storm surge or storm tide which is an abnormally high rise in the water level. Maximum surge height at any location is dependent on many factors including bottom topography, coastline configuration, and storm intensity.

Hurricanes may occur at random; however, the incidence of tropical storm occurrences in the western Gulf of Mexico is not as high as the eastern Gulf of Mexico. Three areas of the Texas coast are listed with their storm occurrences and pertinent data in Table 7. Individual storm damage for the three populated areas of the Texas coast was greater than 50 million dollars and may have reached 500 million dollars.

Hurricanes vary considerably in intensity, track patterns, and behavior upon crossing land, but several processes and their effects are common to all hurricanes. McGowen, et al., (1970), in describing these processes, explained that the storm approach is marked by rising tides and increased wind velocities; generally the longer a storm lingers in the Gulf, the larger the surge of water it pushes ashore as it approaches land. These storm surges are commonly higher in the bays than on Gulf sea beaches, although flooding and pounding waves affect both areas. Hurricane Carla, in 1961, produced a 22-foot surge in Lavaca Bay, Texas; Hurricane Camille, in 1969, produced a 22.6-foot surge at Pass Christian, Mississippi.

TABLE 7

TEXAS STORM DATA BY AREA

Area Storm Type	Total No. 1899-1971	Av.No. Years Of Occurrence	Mean Recurrence Interval			
			5yr.	10yr.	25yr.	50yr.
Corpus Christi						
Tropical Cyclones	41	1.8				
Hurricanes	25	2.9				
Extreme Wind			75	85	95	105
Wave Height			33	37	42	48
Galveston-Freeport						
Tropical Cyclones	35	2.1				
Hurricanes	23	3.2				
Extreme Wind			75	85	95	105
Wave Height			29	32	37	41
Sabine Pass						
Tropical Cyclones	32	2.3				
Hurricanes	15	4.9				
Extreme Wind			80	90	100	101
Wave Height			30	33	38	42

Extreme Wind = Maximum Sustained Wind in Knots

Wave Height = Maximum Height in Feet

Extratropical Cyclones

In addition to the tropical cyclones, extratropical cyclones that may vary greatly in intensity occur in this area, primarily during the winter months. These storms have attained wind speeds as great as 30 to 50 knots. They originate in middle and high latitudes forming on the fronts that separate different air masses. The Gulf of Mexico is an area of cyclone development during the cooler months due to the contrast in temperatures of the warm air over Gulf waters and the cold continental air over the United States. These storms rapidly dissipate, or move on, after moving out over the Gulf of Mexico.

c. Physical Oceanography

(1) Sea Surface Temperatures

Leipper (1954) presents figures for average February and August sea surface temperatures for the Gulf of Mexico (Figs. 27 and 28). According to Leipper, the main feature of the average winter pattern is a gradual drop from approximately 75°F in the south to 65°F in the north in all parts of the Gulf. In the summertime, average temperatures are very nearly uniform at 84°F throughout the Gulf. Years of investigations have shown that considerable deviation from these average isotherms may occur at certain times.

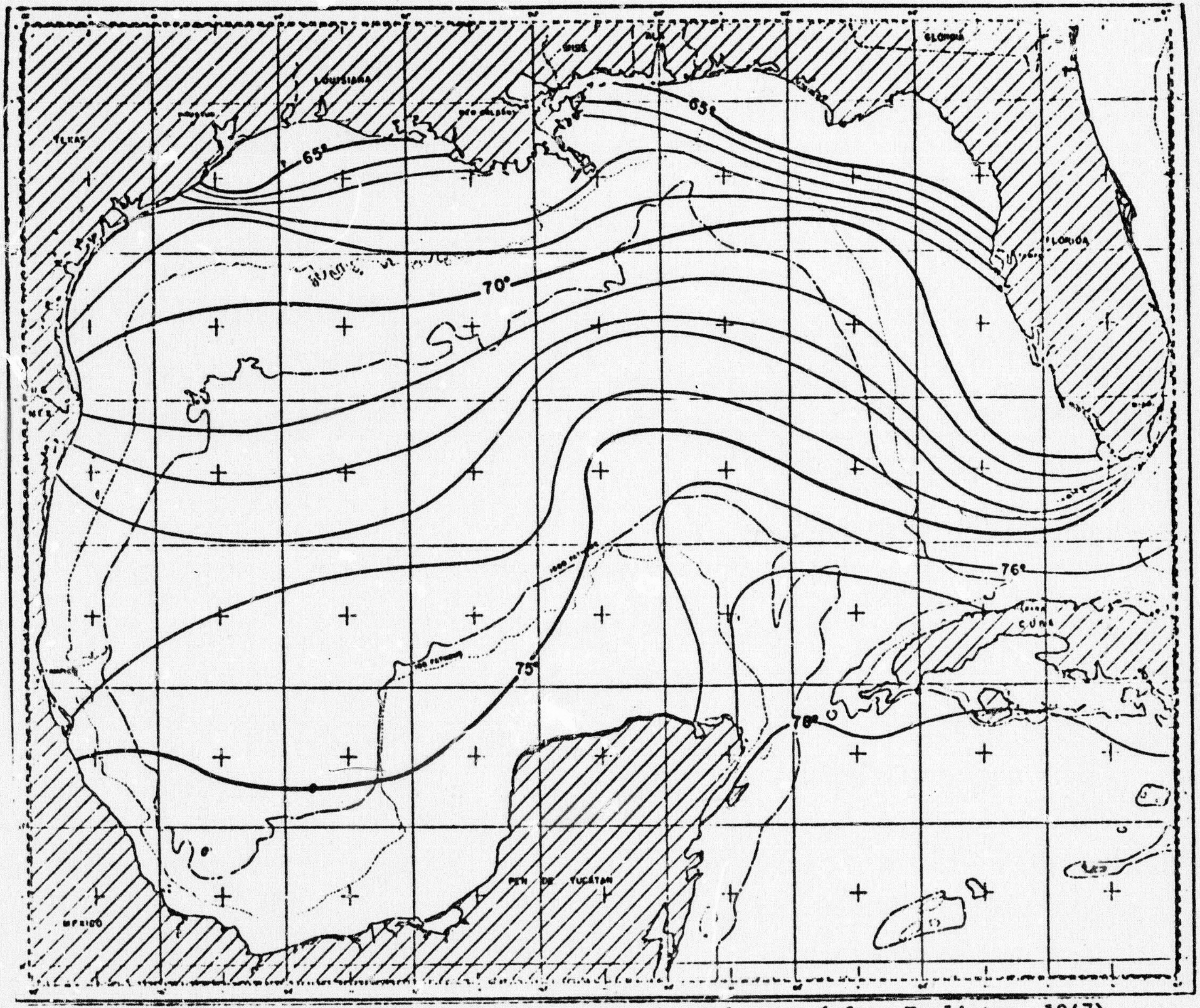

TEXAS
LOUISIANA
MISS
ALA
GEORGIA
FLORIDA
65°
65°
70°
75°
76°
78°
CUBA
PEN DE YUCATAN
MEXICO

Figure 27 Average sea surface temperatures for February (after Fuglister, 1947). (From Leipper, 1954 after Fuglister, 1947).

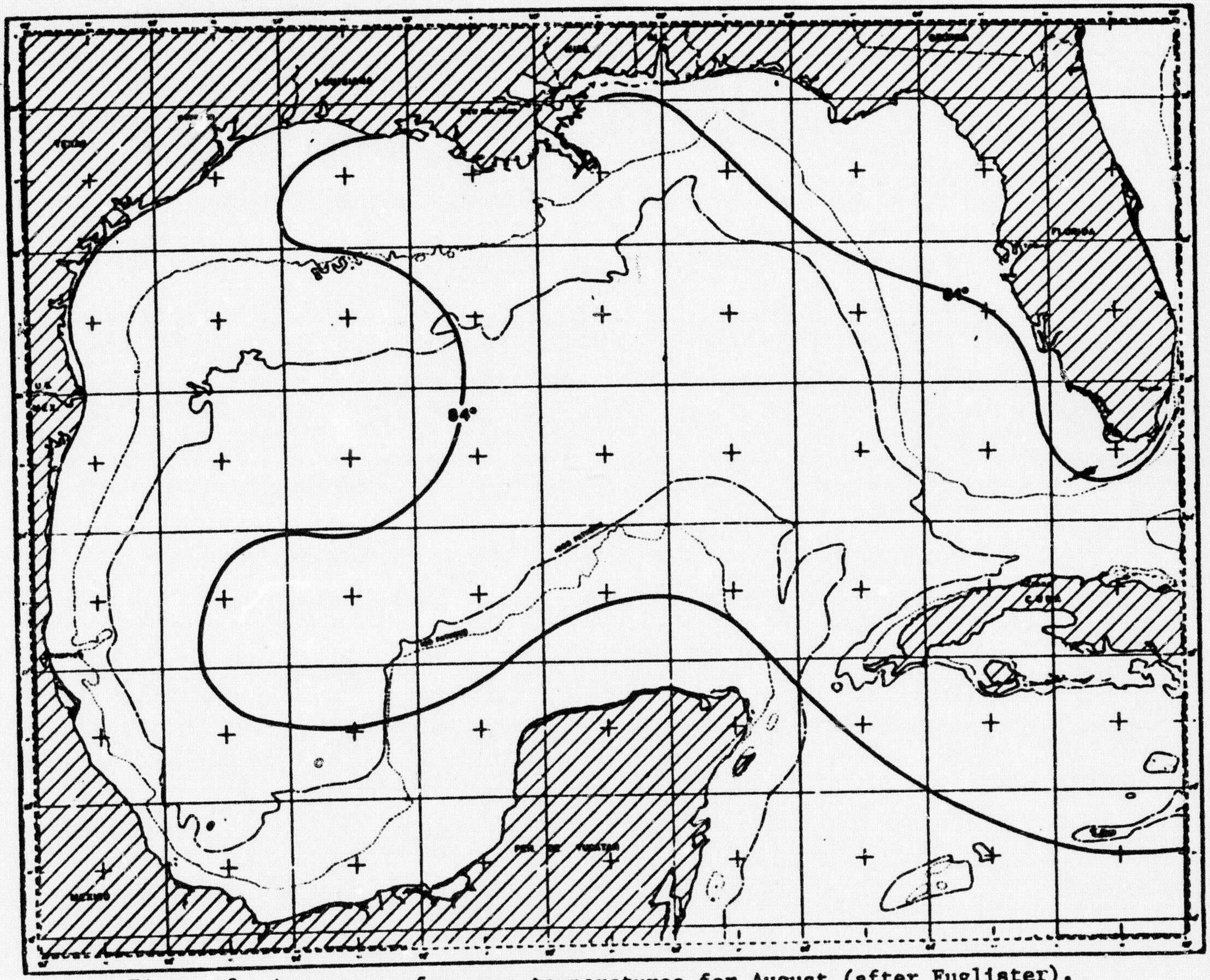


Figure 28 Average surface sea temperatures for August (after Fuglister). (From Leipper, 1954 after Fuglister, 1947).

(2) Salinity

The salinity patterns of the Gulf of Mexico are principally determined by: (1) inflow of ocean waters through the Yucatan Strait, (2) precipitation and inflow of fresh water from land sources, (3) evaporation, (4) circulation and mixing, and, (5) outflow through the Straits of Florida. In the northern Gulf, runoff from the Mississippi and Atchafalaya and from smaller rivers to the east and west gives rise to a band of low-salinity water (Nowlin, 1972). Typical salinities are seen in Figure 29.

(3) Surface Circulation

Water movements in the Gulf of Mexico are controlled by a variety of interacting forces including fresh water inflow from land, currents set up by winds, currents and water transport induced by surface gravity waves, tidal currents associated with internal waves, and movement of water masses due to density differences.

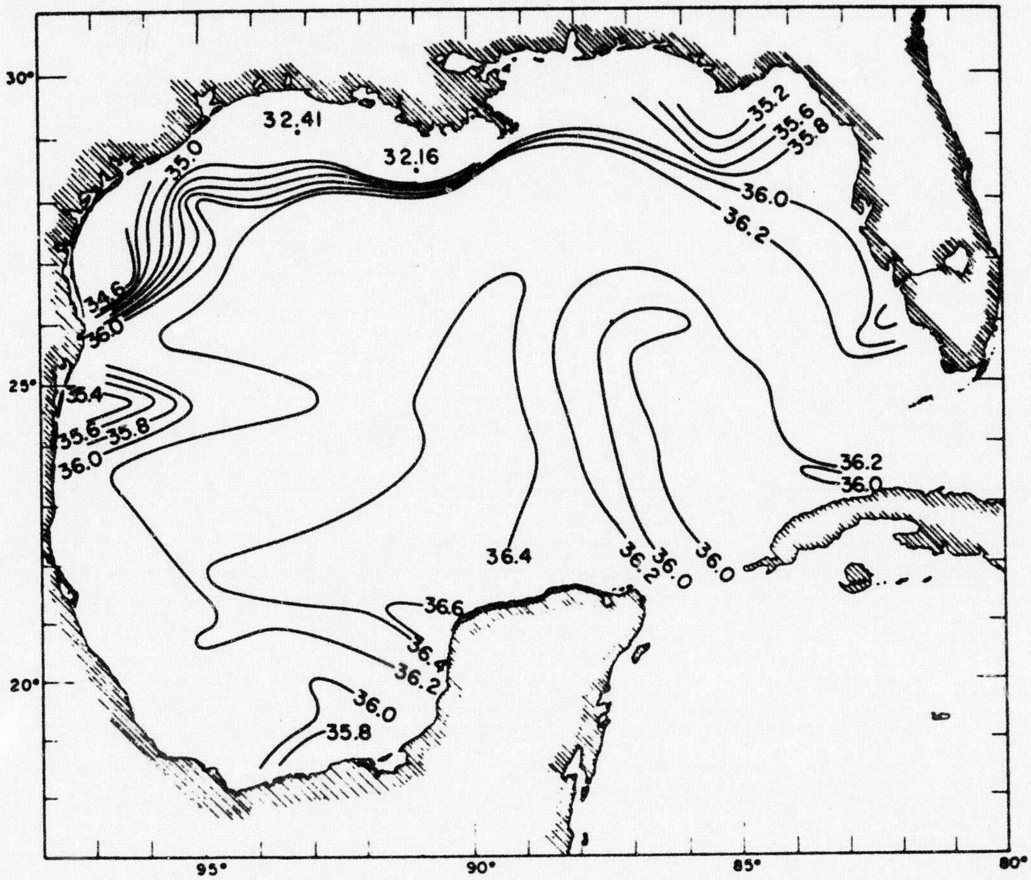

30°
25°
20°
95°
90°
85°
80°
32.41
32.16
35.0
35.2
35.6
35.8
36.0
36.2
34.6
36.0
35.4
35.6
35.8
36.0
36.2
36.0
36.4
36.2
36.0
36.0
36.6
36.4
36.2
36.0
35.8

Figure 29 Typical surface salinities (parts per thousand) in the Gulf of Mexico (from Nowlin, 1972).

The general circulation pattern for the eastern Gulf consists of a clockwise Loop Current flowing in through the Yucatan Strait and out through the Florida Strait (Fig.30). This is essentially an extension of the Yucatan Current which flows into the Gulf, circles to the right and flows out through the Florida Strait to join the Gulf Stream Current. A counterclockwise gyre off the west coast of Florida is a persistent feature, more defined during the winter months, however. The western half of the Gulf has no strong, semi-permanent currents but is characterized by a

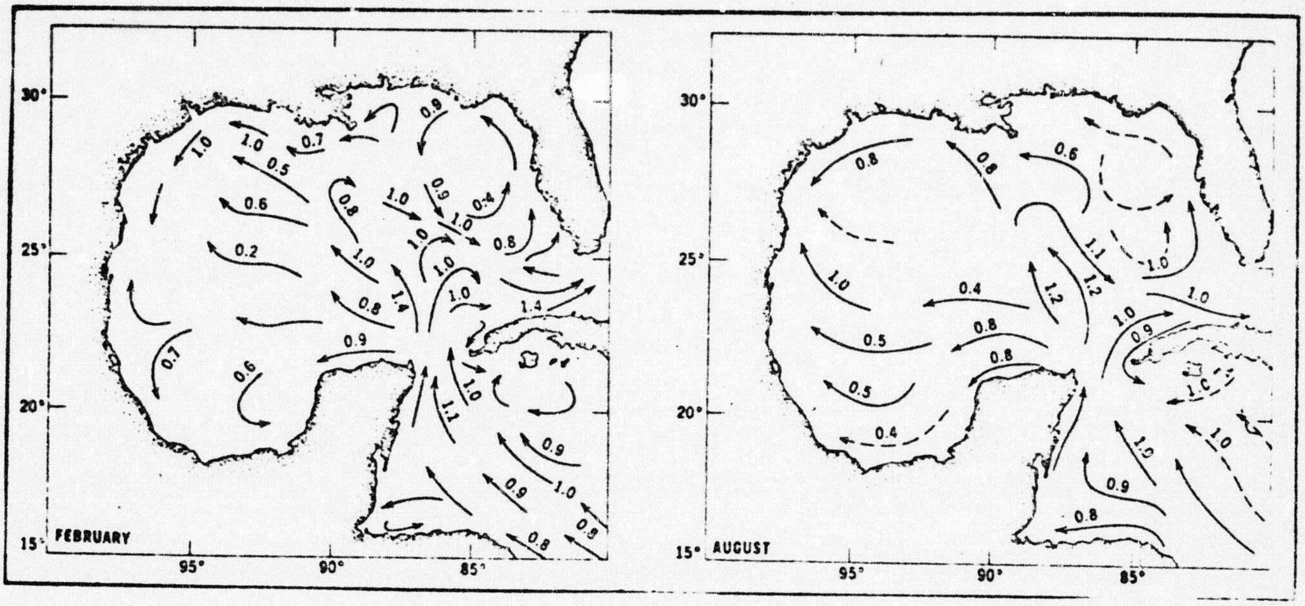

30°
25°
20°
15°
FEBRUARY
95°
90°
85°
1.0
1.0
0.5
0.7
0.9
0.6
0.2
0.8
1.0
0.9
0.4
1.0
1.0
0.8
1.0
1.4
1.0
0.8
1.0
1.4
0.9
0.7
0.6
1.1
1.0
0.9
0.9
1.0
0.8
0.9
AUGUST
0.8
0.8
0.6
1.1
1.2
1.2
1.0
1.0
0.4
0.8
0.5
0.8
0.5
0.4
1.0
0.9
1.0
1.0
1.0
0.9
0.8
1.0

Figure 30. Generalized surface circulation in the Gulf of Mexico inferred from logs of ships at sea. The numbers refer to current speeds in knots, as estimated from ships' drift. (From Nowlin, 1971)

well-defined pattern of winter flow and a highly variable summer pattern (Nowlin, 1971). There is a general westward sweep of currents along the northern shelf west of the Mississippi Delta. Another mass of water moves northward along the Mexican coast to a zone of convergence off Texas. All the currents in the western Gulf seem to flow toward this general zone.

The eastern Gulf shelf from the Mississippi Delta to Cape San Blas is characterized by a very mixed current pattern reflecting influences of variable winds and fresh water inflow upon water mass movements resulting from the Loop circulation. Eastward from Cape San Blas, the current directions reflect a semi-permanent counterclockwise gyre which flows northward along the west coast of Florida, swings westward south of

Apalachee Bay, and turns south off Cape San Blas. There are places and times where this gyre is weak or non-existent. Thus, some bays and inlets, as well as some open beaches, are isolated from tidal and current exchanges.

(4) Tides

The tides of the Gulf of Mexico are small; usually their observed range does not exceed 0.7 meters (Durham and Reid, 1967). Semidiurnal (twice daily) tides are small, and therefore, the tide in the Gulf is considered diurnal (daily) in character. In 1908, Endros (in Grace, 1932) arrived at the conclusion that waters of the Gulf and the Caribbean Sea were a single oscillating body with a tidal period of nearly 24 hours.

According to work by S. F. Grace (1932), the diurnal tide enters through the Florida Straits, progresses counterclockwise around the basin, is reflected by the northwestern and southern coasts and egresses through the Yucatan Channel.

When the moon is near its maximum declination (angular distance from equator), the tide is diurnal and has the greatest range. When the moon is over the equator, the tide has the least range and there may be several days having two highs and two lows. Although tides in the Gulf have a small range they do have important roles in modifying currents and accelerating the movement of water through narrow passages.

(5) Sea and Swell

Waves in the Gulf of Mexico have a mean height of 3 to 4 feet. Higher wave heights occur during the period November, December, January, February and March when stronger winds blow out of the north. Prevailing winds during spring, summer, and early fall are from the southeast and wave heights are generally lower during this period. Waves associated with stroms range considerably higher. During Hurricane Camille (1969) for example, waves 70 feet high were reported offshore.

d. The Biological Environment

For the purpose of discussion of the biology of the offshore environment, the land margin of the continental shelf is functionally defined as the seaward edge of submerged seagrass beds. Where these beds are absent; it is assumed that the shelf begins at the line of total immersion, or mean low water. Table 8 lists representative Gulf of Mexico biota.

Table 8 **Representative Gulf of Mexico Biota**

(1) Phytoplankton

a. Low salinity regime (Mississippi delta)

Diatoms. (Cyclotella, Melosira, Navicula)

b. High salinity regime (open Gulf)

Diatoms. (Nitzchia, Thalassiothrix, Skeletonema, Asterionella, Chaetoceros, Rhizosolenia)

Dinoflagellates. (Triposolenia, Cladopyxis, Heterodinium, Amphisolenia, Gymnodinium)

(2) Zooplankton

a. Holoplankton (remain zooplankton throughout life-cycle)

Chaetognaths (arrow worms)

Ctenophores (sea wasps)

Medusae (jellyfish, etc.)

Crustaceans

- Copepods
- Ostracods
- Cladocerans
- Mysids
- Amphipods

Pteropods (molluscs)

Salps

Pyrosomes

b. Meroplanktonic (are zooplankton only in early life stages)

Tunicates (sea squirts)

Echinoderms (starfish, urchins, etc.)

Cephalopods (squids, octopods)

Table 8 (cont')

- Ectoprocts (worm-like animals)
- Porifera (sponges)
- Annelids (worms)
- Nemerteans (worms)
- Fish Larvae

(3) Benthic Biota

- a. Epiflora (plants on the bottom)
    - Seagrasses
    - Benthic algae
- b. Inflora (plants in the bottom)
    - Interstitial algae
- c. Epifauna (animals on the bottom)
    - Porifera (sponges)
    - Anemones
    - Decapods (Shrimp, Crabs)
    - Demersal Fish
        - Flounders
        - Red Snapper
        - Croakers
- d. Infauna (animals in the bottom)
    - Molluscs
    - Polychaetes (worms)
    - Echinoderms (starfish, urchins, etc.)

(4) Active Swimmers - Nekton

- a. Cephalopod Molluscs (squid)

Table 8 (cont')

- b. Crustaceans (Shrimp, swimming crabs)
- c. Reptiles (Turtles)
- d. Marine Mammals (porpoises)
- e. Elasmobranchs (sharks, skates)
- f. Fish
  - Schooling Fish
    - Sea Robins
    - Mullet
    - Pompano
    - Menhaden
    - Anchovies
    - Herring
  - Non-schooling fish
    - Sailfish
    - Marlin
    - Dorado

(5) Birds (see text)

(1) Phytoplankton

Phytoplankton includes the acellular (unicellular) floating plants and all floating cellular plants such as Sargassum. As plants, all phytoplankers are capable of producing their own food from raw materials by photosynthesis. The ubiquitous distribution and occurrence of phytoplankton in pelagic waters is influenced by several factors. Steidinger (1973) stated that both horizontal and vertical distributions of phytoplankton are dependent on: 1) population origin and life cycles, 2) supply and level of nutrients and growth factors, 3) physiological requirements and adaptability, 4) salinity and temperature, and 5) grazing pressure by herbivores (plant-eating animals). In addition, vertical distribution alone is influenced by: 1) diffusion and water stability, and 2) depth of the lighted zone (euphotic zone).

El Sayed (1972) used measurements of chlorophyll a (a bluish black pigment found in phytoplankton) to calculate estimates of the phytoplankton standing crop (total number or weight of living organisms momentarily present in an environmental unit (Pennak, 1964) for the Gulf of Mexico. Surface chlorophyll a showed higher concentrations (high standing crop) during the winter than at any other season; these were followed by a decrease in the standing crop of phytoplankton during spring, and a gradual increase in summer and fall. In terms of chlorophyll a (sea-surface values and data integrated for the euphotic zone), the Gulf of Mexico is no different from other tropical or subtropical bodies. The average primary productivity of the Gulf was 0.15 g C/m^2/day (El Sayed, 1972).

The Gulf water regime near the fresh water plume of the Mississippi River has higher diversity due to mixing of fresh water and marine genera (Simmons and Thomas, 1962). According to these authors, seasonality of species (presence and abundance) was more variable in the Gulf regime than in the river regime. In both areas, the lowest abundances (standing crop) were noted in November.

Saunders and Fryxell (1972) found the diatom *Rhizosolenia alata* to be the most frequently observed species over the entire Gulf during 11 months of the year. *Guinardia flaccida* was also found in all months. Table 8 lists other commonly occurring phytoplankton genera.

Dinoflagellate distribution was reviewed by Steidinger (1972), who mapped occurrences of 14 frequently found species in the Gulf. Species diversity of dinoflagellates was found to be higher offshore (where it occasionally exceeds diatom diversity) than nearshore, while dinoflagellate abundance was higher nearshore than offshore.

Steidinger (1973) later surveyed the phytoplankton of the eastern Gulf and outlined four broad types of assemblages: 1) estuarine, 2) estuarine and coastal, 3) coastal and open Gulf, and 4) open Gulf. The assemblages described by Steidinger are not meant to imply strict groupings. Many species are found in more than one area, being subject to current and wind patterns. The four groupings show certain associations such as the greater dinoflagellate diversity in open Gulf waters.

(2) Zooplankton

Zooplankton distributions and occurrences are relatively continuous in pelagic waters. In general, they are influenced by the same factors that affect phytoplankton distribution and occurrence. Inorganic nutrients and depth of the lighted zone are not as immediately important to zooplankton as to phytoplankton, but these factors affect distribution and abundance in that greater availability of nutrients and light allow higher primary productivity and consequently a greater food supply for zooplankton.

Data on zooplankton for the Gulf of Mexico shelf waters are limited. Most of the zooplankton studies were restricted to certain groups of organisms and included only the inshore waters. Khromov (1965) indicated a zone of low zooplankton density east of Galveston;

southwest of Galveston the nearshore density exceeded 0.5 g/m^3 in the shallow coastal waters with lower densities seaward.

The most important grazers (herbivores) are the copepod crustaceans, which are the most abundant zooplanktonic group in any given plankton sample (Raymont, 1963). The distribution of copepods is dependent on factors mentioned previously for phytoplankters. The herbivores feeding habitat superimposes a localized abundance (patchiness) on the general distribution pattern. Where phytoplankton populations become abundant, copepod populations will also flourish.

Euphausiid crustaceans are also prominent members of the zooplankton assemblage. Feeding habits of euphausiids have variously been described as herbivorous, carnivorous (meat-eating) and detritivorous (organic or inorganic particulate matter eaters). Table 8 lists common constituents of Gulf of Mexico zooplankton.

(3) Benthic Biota

Assemblages of the benthic organisms listed in Table 8 are generally distinct for each of the three neritic zones (supratidal or supralittorla, intertidal or littoral, and subtidal or sublittoral), but specific species may be found in more than one zone. Zonation is characterized more by dominant species than by distinct assemblages of numerous species.

The benthic community is, in general, affected and defined by the same factors that influence the waters above the bottom. Additional factors to consider for the sea bottom alone are: 1) nature of the substrate, 2) nature of the sediment, and 3) sub-bottom temperatures, salinity, oxygen and pH. The substrate may be hard or soft depending on the amount and nature of sedimentation, and the degree of scouring by horizontal currents. Sediment type is usually described by percentages of carbonates, evaporities, sand, silt, and clay. The benthic environment becomes more stable at greater depths, i.e., it is less affected by physical forces such as currents, waves and storm surges. Temperature and salinity data tend to fluctuate less and have smaller ranges of values than in shallow water areas closer to the air-sea interface.

Benthic communities of offshore areas can be broadly described as shallow shelf communities, deep shelf communities, and slope communities. Within these broad areas, more specific communities can be described for shrimp grounds, sand bottoms, silt and mud bottoms, rocky bottoms, and hard banks.

Collard and D'Asaro (1973) illustrated the shallow shelf, deep shelf, and slope assemblages for offshore communities. They are but three of eleven assemblages described by these authors, the others being inshore communities. Differences within each assemblage are probably more significant than the differences between assemblages. The differences are functions of depth and latitudinal differences, and the faunal assemblages were described by the authors as indicating Carolinian province (shallow shelf) and West Indian province (deep shelf) affinities.

Parker (1960) found that, for the bottom assemblages of Gulf of Mexico off the Texas and Louisiana coast, variations occur within the major associations according to sediment type. Assemblages living within silty clays in the intermediate shelf community are completely different in composition from those on sand bottom at the same depth. Certain species, however, bridge the two sediment types to create larger associations. Studies of the continental shelf in other parts of the world and in all oceans proved that the same basic assemblages listed here occupy similar depths in the same latitudes (Parker, 1960).

(4) Active Swimmers - Nekton

Nekton for the offshore waters are represented by five major taxonomic categories - marine mammals and reptiles, the fishes, the cephalopod molluscs (octopuses and squid) and certain crustaceans (shrimp and swimming crabs). Individuals of this group commonly but not always, range over broad areas, thus participating in several biotic communities. For example, shrimps have a pelagic planktonic larvae, an estuarine juvenile and a pelagic adult. However, most nekton is limited in geographic and vertical ranges by the same environmental conditions as less mobile organisms, i.e., temperature, salinity, available food, and types of bottom.

The nektonic component of the environment can be divided into strictly open-water nekton, and nekton which spend some portion of their lives in nearshore, estuarine, or marsh waters. Many of the finfish of commercial and sportfishing importance are strictly open-water residents, such as the red snapper, various groupers, sailfish, and marlin. Of particular importance from commercial and sportfishing standpoints are the species which spawn in open water, spend their early lives in fresh, brackish or estuarine waters, and return to deeper waters as adults (semi-catadromous species).

Many fish are demersal; that is, they have a particular habit of living on, or just above the sea bottom. The distribution and abundance of these fish are generally regulated by sediment type and the bottom communities that supply food.

Data by James et al. (1972) from fish collections on the continental shelf in 1971 suggested a greater species diversity for the inner shelf and greater abundance on the outer shelf, with the intermediate shelf being intermediate in fish diversity and abundance. Catches on the inner shelf are seasonally quite variable and tend to be dominated by species which utilize the estuarine habitat in part of their life histories.

(5) Birds

There are apparently only a few species of pelagic birds and most of these occur only in small numbers. Pelagic birds spend their entire life on the open waters of the sea except for returning to land to breed.

Woolfenden and Schrieder (1973) suggested that the Wilson petrel is one of the few species of open Gulf waters that occurs regularly in fairly large numbers. Other species listed as occurring included gannets, jeagers and boobies. However, none are abundant and little is known concerning their distribution. Lowery (1960) described the species that had been recorded in Louisiana coastal waters. However, these were basically the same as reported above.

(6) Unique Environments

The northern Gulf of Mexico has many unique environments. These environments range from the nearshore features, (i.e., the mangrove swamps of Florida, marshes of Louisiana, and beaches of Texas and Florida) to the offshore barrier islands of Mississippi and undersea reefs of Texas and Florida. A detailed discussion of the mangrove swamps, marshes, beaches, and barrier islands may be found in Section B.2.b.

Probably the most unique of all of these features are the undersea reefal features. The most prominent of these features are the Florida Middle Ground and the Flower Gardens (East and West) on the Texas OCS.

The Florida Middle Ground is an extensive area located along the barrier edge of the West Florida Shelf approximately 93 miles south of the northwest Florida coast and 100 miles northwest of Tampa. It is an area of steep-profiled escarpments and prominences, an area that is poorly defined in lateral extent by gradation of topographic and biotic features to the surrounding bottom and is a region of limestone outcrops on a drowned karst topography (Austin and Jones, unpublished ms.). The outcrops are probably Pleistocene reefs which flourished during the last interglacial, or Sangamon, period (Brooks, 1962). Depths throughout the region vary between 84 and 138 feet. Prominences may rise 36 to 48 feet above the surrounding bottom.

The Flower Garden Banks are 2 topographic highs on the Texas OCS approximately 110 miles SSE of Galveston, Texas. The larger structure is West Flower Garden Bank; the smaller structure is East Flower Garden Bank. They were first identified in survey work by Coast and Geodetic Survey in 1936 (Shepard, 1937). Stetson (1953) suggested that the banks were capped by coral reefs, and Pulley (1963) reported these reefs to be live and flourishing.

The Flower Garden Banks are members of a series of pinnacles that rise abruptly from the smooth, sediment covered Outer Continental Shelf and slope off Texas and Louisiana. Figure 31 shows over 60 such banks with most of them clustered along the 100 fathom depth contour offshore of Western Louisiana and Eastern Texas. The origin of many of these pinnacles, and the Flower Gardens specifically, is the result of piercement salt domes or salt plugs, which have thrust upward and warped and folded the overlying rock strata (Edwards, 1971).

The flourishing coral reefs which cap these two banks are presently considered to be the northernmost thriving tropical shallow water coral reefs on the eastern coast of North America. They are apparently part of a discontinuous arc of thriving coral reefs and isolated hermatypic (reef-building) coral heads that ring the Gulf

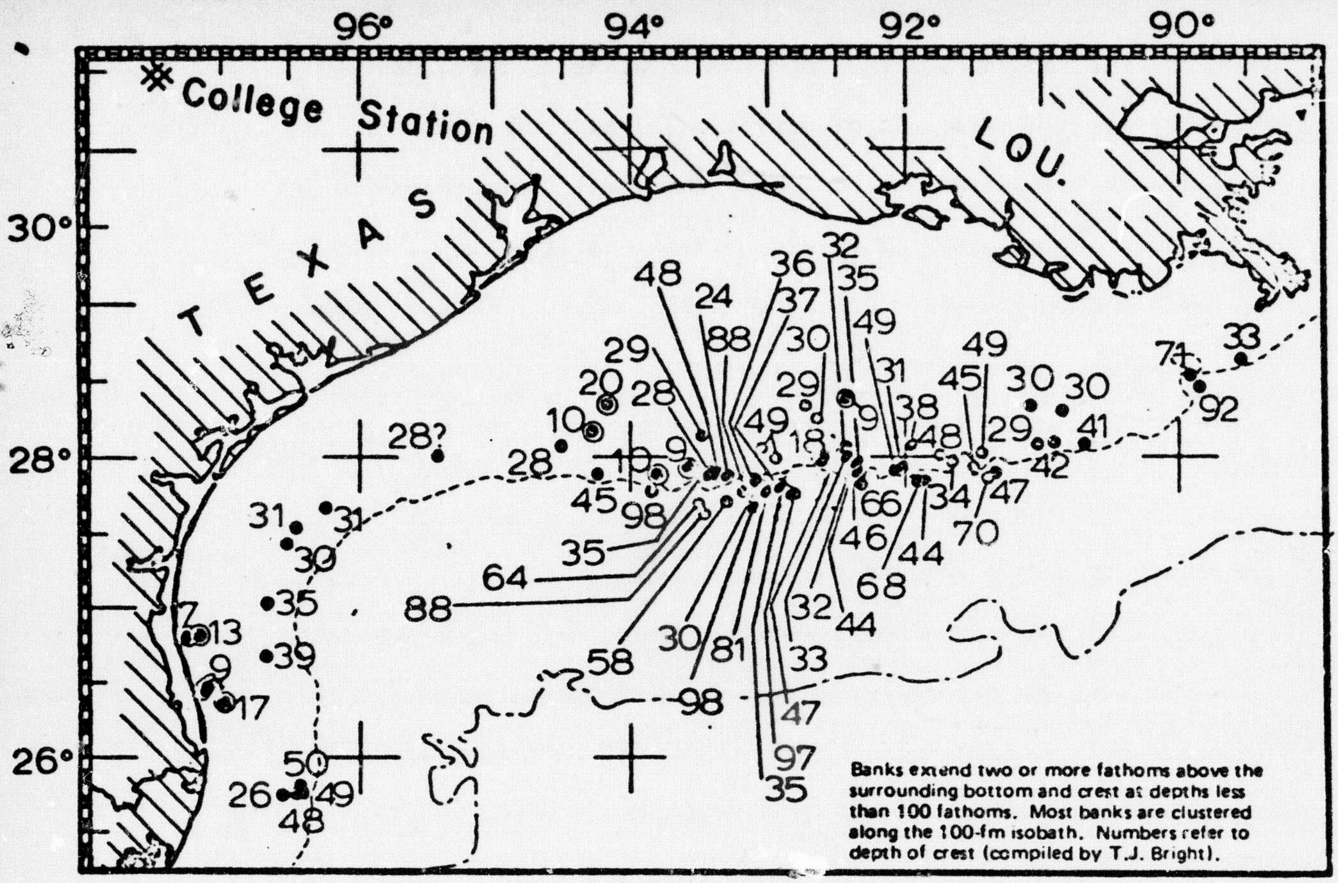

96°
94°
92°
90°
30°
28°
26°
College Station
TEXAS
LOU.
Banks extend two or more fathoms above the surrounding bottom and crest at depths less than 100 fathoms. Most banks are clustered along the 100-fm isobath. Numbers refer to depth of crest (compiled by T.J. Bright).

Figure 31 DISTRIBUTION OF SUBMARINE BANKS IN THE NW GULF

of Mexico harboring elements of the Caribbean reef fauna. Other hard banks in the northern Gulf (notably Stetson Bank and Three Hickey Rock) support coral type communities, but the coral are ahermatypic (non-reef-building), being mainly soft corals and hart encrusting milleporan type (fire coral).

e. Natural Phenomena Unique to Area with Potential to Cause or Contribute to Environmental Impacts of Proposed Action

Hurricanes and tropical cyclones present the greatest natural hazard in the Gulf of Mexico. The intensity of tropical cyclones may range from weak, barely noticeable but possibly developing areas of bad weather, to large and intense storms (hurricanes) with maximum winds approaching 200 miles per hour. During an average year, off the Gulf and Atlantic Coasts, there are fewer than ten tropical cyclones, of which about six develop into hurricanes. Over the last 10 years, these caused in an average year, the death of 50 persons between Texas and Maine, and property damage exceeding $400 million.

Most of the damage and deaths along the Texas coast are due to flooding caused in the low lying areas by the surge of high waves as the hurricane approaches, rain upon impact on the area and flooding from rivers and local runoff in the storm aftermath. Serious flooding occurs up to the 20 foot elevation line which covers most of the coast and millions of acres of low lying ground inland. Although development may continue at a high rate along the low lying areas of the Texas coast, hazards from tropical storms and hurricanes compounded with projected land subsidence could decrease the feasibility of high growth.

Of lesser importance in the Gulf of Mexico is the risk from earthquakes. No known damage has been recorded from earthquakes on an offshore oil platform or installation in the Gulf of Mexico. Most of central and all of southern Florida lie in an area where the occurrence of seismic hazards is extremely unlikely (Figure 9 , Algermissen, 1969). Northern Florida and Western Mississippi lie in Zone 1 risk area which means that there is some danger of earthquakes of low intensity (ones which would not do damage to buildings). Small quakes have been reported in an area approximately 250 miles south of Pensacola, Florida. Because of the geological similarity of the land areas surrounding the Gulf and the adjacent continental shelf, one can reasonable extend the seismic risk zone boundaries some distance offshore.

In the map areas of the western Gulf of Mexico (Figure 9), seismic risk for the area is shown as zero (Algermissen, 1969). This appears to be a rather unique area due to the lack of seismicity. No earthquakes of any notable intensity have been recorded for this area and only two earthquakes of notable intensity have occurred in the Gulf near this area, neither of which produced damaging tsunamis nor were they considered well located events.

Complete assurance that a damaging earthquake will not occur in this area can never be made due to the fact that accurate locations and measurements of earthquakes is a fairly recent ability of the science. Three areas of zero seismic risk, i.e. southern Florida, western Florida, southern Alabama and Mississippi, and eastern Texas are shown on the NOAA Seismic Risk Map of the United States. Eastern Texas and the adjoining part of the Gulf of Mexico appear to be the most seismically quiet areas of the three zones.

3. Pacific Region

a. Geology

(1) Southern California and Santa Barbara Channel OCS

(a) General

The following discussion was abstracted primarily from Parker (1971), Curran et al. (1971) and text supplied by the U.S. Geological Survey.

The Southern California Borderland is a complex of basins, islands, banks, ridges and submarine canyons. The shelf edge, represented by the Patton Escarpment, is over 150 km from shore. The basins reach depths of over 2000 meters (San Clemente Basin-2107m) while some of the ridges and banks break the surface (Begg Rock). Submarine canyons are present from the Mexican Border to the northern limit of the borderland, the Santa Barbara Channel. Depths at the base of the Patton Escarpment approach 4000m. Figure 32 depicts the major geomorphic features of the borderland area.

Structural and Stratigraphic Trends

The structural character of the southern California Borderland is dominated by a complex system of faults which gives the area much of its basin-ridge morphology. Two dominant structural trends exist as offshore extensions of major onshore geomorphic provinces. North of the Channel Islands, offshore structural elements follow the E-W trend of the adjacent Transverse Range system while, to the south

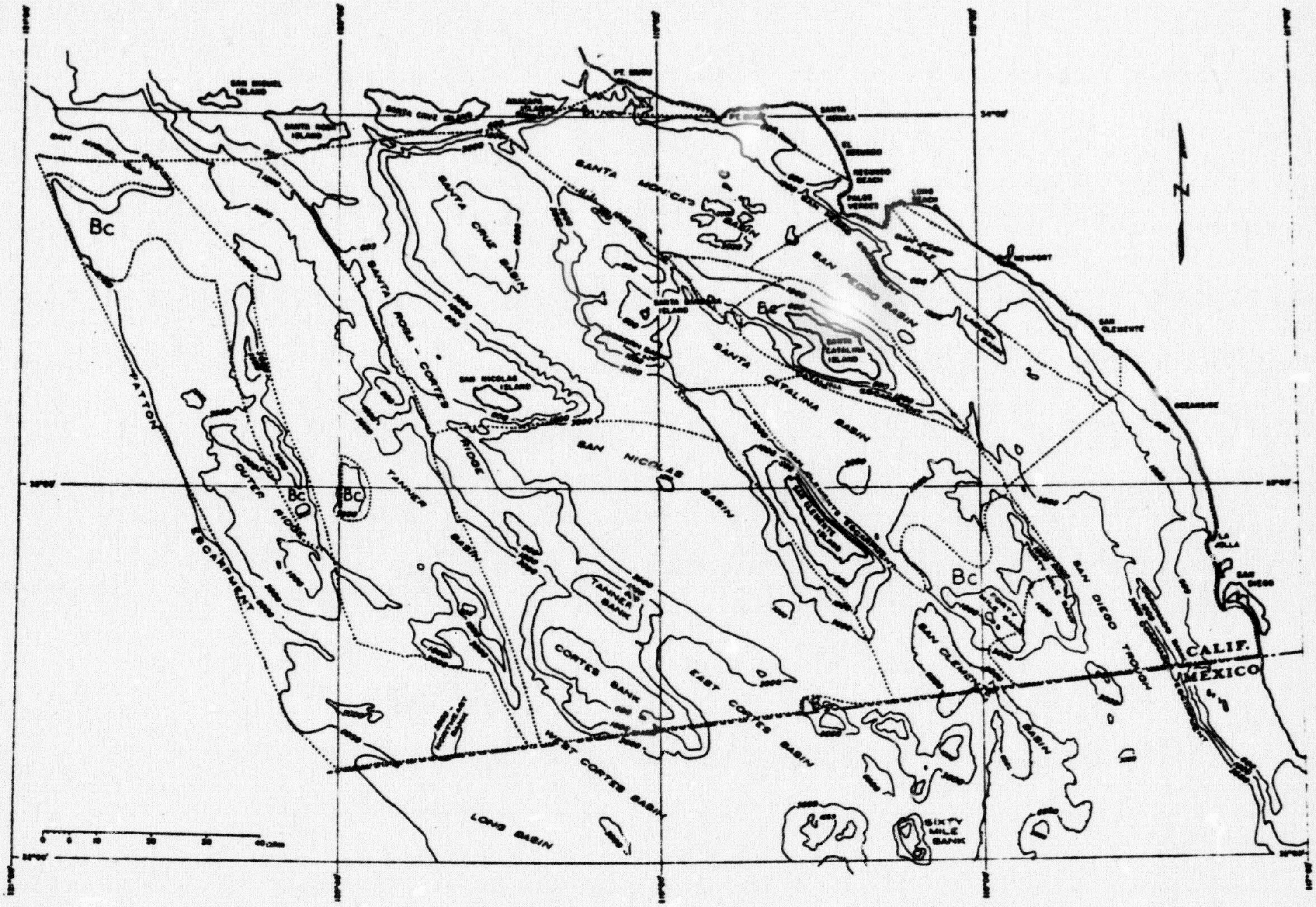

SAN MIGUEL ISLAND
SANTA ROSA ISLAND
SANTA CRUZ ISLAND
ANACAPA ISLAND
PT. MUGU
SANTA MONICA
EL SEGUNDO
REDONDO BEACH
PALOS VERDES
LONG BEACH
NEWPORT
SAN CLEMENTE
OCEANSIDE
LA JOLLA
SAN DIEGO
CALIF.
MEXICO
N
SANTA MONICA BASIN
SAN PEDRO BASIN
SANTA CRUZ BASIN
SANTA BARBARA ISLAND
SANTA CATALINA ISLAND
SANTA CATALINA BASIN
SAN NICOLAS ISLAND
SAN NICOLAS BASIN
SANTA ROSA - CORTES RIDGE
TANNER BASIN
TANNER BANK
CORTES BANK
EAST CORTES BASIN
WEST CORTES BASIN
LONG BASIN
SAN CLEMENTE ISLAND
SAN CLEMENTE BASIN
SAN DIEGO TROUGH
SIXTY MILE BANK
PATTON ESCARPMENT
OUTER RIDGE
Bc
Bc
Bc
Bc
Bc

Figure 32. Geomorphic features of the Southern California Borderland (from Parker, 1971).

of the northern island group, the offshore structural regime parallels the NW-SE character of the onshore Peninsular Ranges province.

Major NW-trending fault zones identified on the borderland include, from west to east: the Patton Escarpment, the west edge of the Santa Rosa-Cortes Ridge, the east margin of Santa Cruz and San Nicolas Basins, the San Clemente Island Escarpment-northeast margin of the San Clemente Basin and the Catalina Escarpment. The active Newport-Inglewood fault zone extends southeast from the Santa Monica mountains to the shelf offshore Laguna Beach.

Major offshore faults that have a general E-W trend include the Santa Monica complex which also extends onto islands of the northern group, and the cross-fault which marks the north edge of the San Nicolas Basin.

In addition to these major features, numerous smaller faults exist throughout the borderland, associated primarily with the ridges and basin margins. These faults are highly varied in age and type of displacement.

Earthquake epicenters on the borderland, although poorly located and less densely distributed than on the mainland, suggest recent activity associated with some offshore faults, particularly the San Clemente Island-Agua Blanca fault system.

Seismic records have revealed numerous subsurface folds in the borderland. Although regional trends are difficult to identify from available records, Vedder et al. (1974) interpret major folds on the outer part of the borderland as more broad and nearly symmetrical (Fig. 33) than the tight, asymmetric folds found within the productive onshore basins.

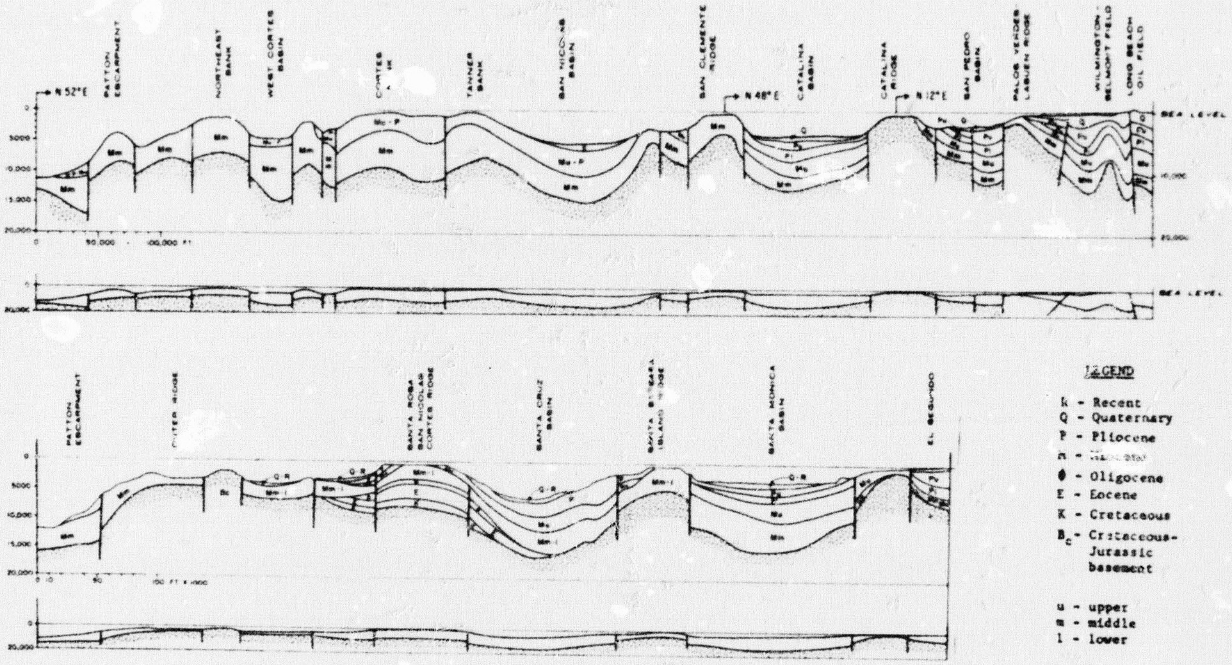

N 52°E
PATTON ESCARPMENT
NORTHEAST BANK
WEST CORTES BASIN
CORTES BANK
TANNER BANK
SAN NICOLAS BASIN
SAN CLEMENTE RIDGE
N 48°E
CATALINA BASIN
CATALINA RIDGE
N 12°E
SAN PEDRO BASIN
PALOS VERDES-LASUEN RIDGE
WILMINGTON-BELMONT FIELD
LONG BEACH OIL FIELD
SEA LEVEL
0
5000
10,000
15,000
20,000
50,000
100,000 FT
Mm
Mu-P
Pu
Pl
Q
OUTER RIDGE
SANTA ROSA SAN NICOLAS CORTES RIDGE
SANTA CRUZ BASIN
SANTA BARBARA ISLAND RIDGE
SANTA MONICA BASIN
EL SEGUNDO
Bc
Mm-l
Q-R
E
0 10 50 100 FT x 1000
LEGEND
R - Recent
Q - Quaternary
P - Pliocene
M - Miocene
Φ - Oligocene
E - Eocene
K - Cretaceous
Bc - Cretaceous-Jurassic basement
u - upper
m - middle
l - lower

Figure . Regional cross sections of the Southern California Borderland off El Segundo and Long Beach. The upper section in each pair has a 5X vertical exaggeration; the lower, none. (from Parker, 1971)

On the mainland coast, thick successions of upper Cretaceous sedimentary rocks are exposed in the Santa Ynez Mountains, Santa Monica, the Santa Ana Mountains, and between Oceanside and San Diego. In addition, wells drilled in the vicinity of the town of San Clemente have encountered Upper Cretaceous strata in the subsurface. An Upper Cretaceous sequence which may be as much as 10,000 feet (3,050m) thick is exposed in the western and southern portions of San Miguel Island. Correlative strata have been penetrated by wells on Santa Cruz Island, beneath the shelf north of San Miguel and beneath the central Santa Barbara Channel. Possible Upper Cretaceous rocks have also been reported on Santa Rosa Island.

Paleocene rocks are absent in the San Diego district and the Eocene shallow-marine sandstone and shale beds, including non-marine conglomerate lenses, are about 3,000 feet (910m) thick. On San Miguel Island, Paleocene sandstone, shale, and conglomerate beds may be as much as 1,500 feet (460m) thick and probably represent outer shelf and upper slope conditions of deposition. Less than 300 feet (90m) of correlative shallow water deposits are exposed on Santa Cruz Island. Marine sandstone and shale beds of Eocene age that have a combined thickness of more than 4,000 feet (1,220m) are present on and beneath the three large islands of the northern group. These strata reflect gradually deepening conditions of deposition through time. In the subsurface section beneath the Santa Barbara Channel, Eocene strata are thick, widespread, and probably continuous between the outcrops on the Channel Islands north and the mainland coast.

On the east and southeast sides of the Los Angeles basin, lower Miocene marine strata interfinger with non-marine beds to the north, however, toward the coast they rest gradationally on red beds and are increasingly finer grained as the section thickens in the same direction (Yerkes, et al., 1965). Lower Miocene rocks are not known to be present in the area between the San Joaquin Hills and the Mexican border and on the southern group of islands.

Marine strata of Pliocene age generally are restricted to existing deep depositional basins and their closely adjacent margins. In the vicinity of Ventura, the Pliocene section is 15,000 feet (4,575m) or more thick and may be more than 14,000 feet (4,270m) thick in the central Los Angeles basin.

Thick accumulation of marine and non-marine deposits of Pleistocene and Holocene age are found along the mainland coast and adjacent and outer basins. On the islands, these beds are limited chiefly to marine terrace deposits of late Pleistocene age and dune and slopewash cover of Holocene age.

(b) Hydrocarbon Potential

A discussion of petroleum potential offshore southern California relies heavily on present knowledge and development of presumably analogous onshore regions such as the Ventura, Santa

Barbara and Los Angeles Basins. Published descriptions of offshore rock sections suggest that a number of the shaly or silty units ranging in age from late Cretaceous to Pliocene contain sufficient carbonaceous or other organic matter to constitute potential source rocks for petroleum. Whether or not the deformational and thermal history of any of these units has been appropriate for the genesis and migration of fluid hydrocarbons is not known.

Santa Barbara Channel

Since the first major offshore petroleum discovery (Offshore Sunniland field) in 1958, seven additional oil fields and four gas fields have been discovered beneath State waters of the Santa Barbara Channel. Prior to that time, offshore oil and gas development involved the extension of onshore production areas.

A major Federal OCS lease sale was held for the Channel area in early 1968, with 71 tracts eventually leased. Activity on these tracts through 1971 has resulted in the discovery of one producing oil field (Dos Cuadras Offshore) and at least seven additional, potential fields.

Through 1972, the Santa Barbara Channel area had produced 1.3 billion bbl. of oil and over 3 trillion cubic feet of gas, or 8 and 10 percent, respectively, of total State production during the same period (U.S. Geological Survey, 1974). All current production occurs from strata ranging in age from Eocene through Pliocene.

With respect to future petroleum potential, the continuation of favorable onshore stratigraphic and structural trends has been confirmed offshore in the Santa Barbara Channel. Fractured marine shales and numerous potential structural traps have been identified along with thick sandstone sections that offer good reservoir capabilities.

(c) Geologic Hazards

The following text discusses potential geologic hazards for all California OCS areas.

Potential geologic hazards to oil and gas resource development offshore California involve primarily the irregular subsea topography and seismic activity along the complex fault systems of the area. This fault activity is a manifestation of large-scale crustal movements that are occurring along the entire western coast of North and South America, as well as in other parts of the world. Other potential hazards along coastal California include mass wasting (landslides, slumps, creep), ground surface erosion, onshore flooding, land subsidence, and expansive soils. Submarine topography has been discussed previously; remaining hazards are discussed briefly below, as abstracted from California Division of Mines and Geology (1973).

Fault Displacement and Earthquakes

A fault is a fracture in the crust of the earth along which there has been movement or displacement. Active faults are the main sources of earthquakes. Two aspects of fault displacement need be considered in conjunction with the design and placement of structures:

1. The effects that sudden displacement along faults may have on structures built across their traces.
2. The relatively slow effects of fault creep--the gradual ground distortion and movement along a fault trace not accompanied by significant earthquakes.

Fault displacements involve forces so great that the only means of limiting damage to man-made structures is to avoid areas along traces of active faulting or to design structures to accommodate the expected displacement.

Although much of the offshore area has not been mapped in detail, active faults can be identified and located accurately through detailed geologic mapping, seismic study, trenching, drilling, and geophysical work. Faults must be identified and located before platform and pipeline locations are determined.

The California Division of Mines and Geology (1973) published a preliminary seismic risk map (Fig. 34) which categorizes the State into three zones of maximum earthquake intensity and probable damage. Virtually all of the coastal areas lie within zones II and III signifying moderate to major potential structural damage.

Mass Wasting

Mass wasting involves the downslope movement of masses of earth material under the influence of gravity. Movement may be rapid

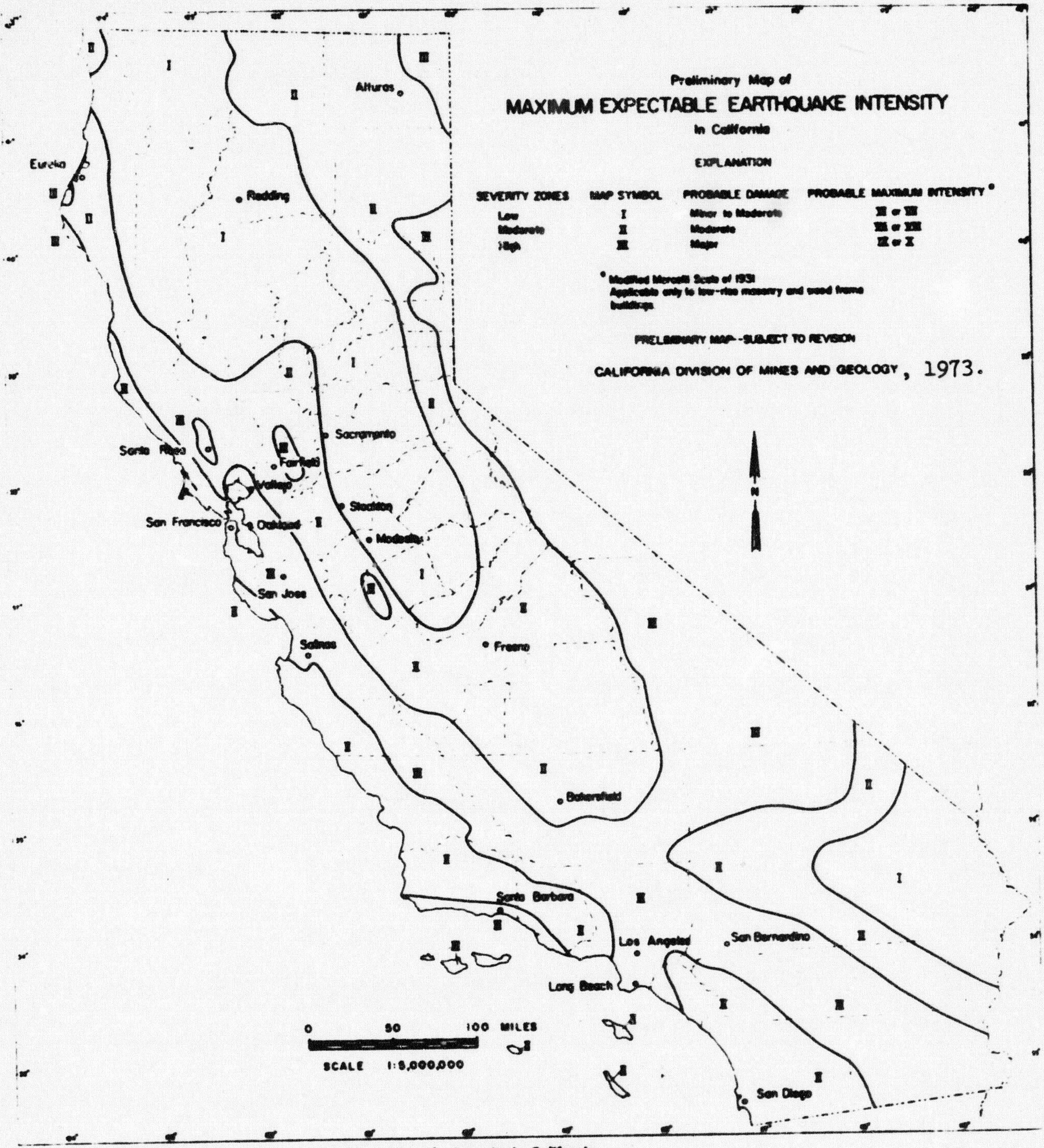

Preliminary Map of
MAXIMUM EXPECTABLE EARTHQUAKE INTENSITY
in California
EXPLANATION
SEVERITY ZONES
MAP SYMBOL
PROBABLE DAMAGE
PROBABLE MAXIMUM INTENSITY*
Low
I
Minor to Moderate
VI or VII
Moderate
II
Moderate
VII or VIII
High
III
Major
IX or X
* Modified Mercalli Scale of 1931
Applicable only to low-rise masonry and wood frame buildings
PRELIMINARY MAP--SUBJECT TO REVISION
CALIFORNIA DIVISION OF MINES AND GEOLOGY, 1973.
N
Alturas
Eureka
Redding
Santa Rosa
Sacramento
Fairfield
Vallejo
San Francisco
Oakland
Stockton
Modesto
San Jose
Salinas
Fresno
Bakersfield
Santa Barbara
Los Angeles
San Bernardino
Long Beach
San Diego
I
II
III
0
50
100 MILES
SCALE 1:5,000,000

Figure 34 Preliminary map of maximum expectable earthquake intensity in California.

(landslide, slumping, mudflow) or so slow (creep) that a change of position can be noted only over a period of weeks or years. The areal size of a slide can range from several square feet to several square miles. Thicknesses may range from less than a foot to several hundred feet. Mass wasting, both rapid and slow, is a common problem in the hillside areas of coastal California and can be anticipated along unstable slopes within certain offshore areas as well.

Erosion Activity

Erosion generally involves two somewhat distinct problems--the wear and removal of material from one site and its disposition at another. The removal of soils through erosion can be damaging in situations of sheet and gully erosion of land surfaces, the windblown denudation of land, the erosion of stream courses and banks, and the erosion of coastal cliffs, dunes and beach areas. Deposition affects flood plains, rivers, lakes, reservoirs, and may clog drainage structures. Activities by man may frequently accelerate erosional phenomena.

Expansive Soils

Expansive soils are earth materials which greatly increase in volume when they absorb water and shrink when they dry out. Expansion most often occurs in clay materials, primarily montmorillonite. Although not common, expansive rocks are also known, these are claystones or altered volcanic tuffs which contain large proportions of montmorillonite. The basic cause of expansion is the attraction and absorption of water into the expandable crystal lattices of the clay materials. The water may be derived from moisture in the air or subsurface ground water. When buildings are placed on expansive soils, foundations may rise during the west season and fall during the dry season. Movements may vary under different parts of a building with the result that foundations crack, various structural portions of the building are distorted, and doors and windows are warped so that they do not function properly.

Subsidence

Subsidence of the land surface, as a result of the withdrawal of oil and gas, occurs in much the same way as does subsidence from groundwater withdrawal. That is, as pore pressures are reduced in reservoirs by fluid withdrawal, the overburden load is gradually transferred from the fluids to reservoir rocks with poorly consolidated sediments compacted.

Surface deformation, associated with oil and gas field operations in California, has manifested itself in the differential subsidence of lands centering on the fields, inwardly directed horizontal displacements, and faulting. Twenty-two fields have experienced differential subsidence, three have experienced horizontal subsidence, and five have experienced faulting (Yerkes and Castle, 1969).

Differential subsidence is the most common and widespread of the surface effects. Subsidence centers over and extends well beyond the producing areas and frequently takes the shape of a bowl. Large subsidence bowls have been documented over the Wilmington oil field, the Huntington Beach field, the Long Beach field, and the Inglewood field.

The area that subsided over the Wilmington field is intensively industrialized and initially was only 5 to 10 feet above sea level. By 1966, subsidence had placed much of the area well below sea level and extensive construction of dikes and raising of dock facilities were required. Surface deformation within the subsidence bowl had caused extensive damage to pipelines, railroad tracks, and buildings. Sinking was halted by repressurization in conjunction with the secondary recovery of oil.

Seeps

Oil and gas seeps have occurred both onshore and offshore for many years in southern California. All of the active offshore seeps on the borderland have been found between Point Conception in Santa Barbara County and Huntington Beach in Orange County. The largest concentration of these appears to be in the Santa Barbara Channel area.

(2) Central and Northern California

(a) General

The following discussion is abstracted primarily from Rusnak (1966), Hoskins and Griffiths (1971) and text supplied by the U.S. Geological Survey.

The onshore limit of the central and northern California continental margin is defined by the western front of the California Coast Ranges, which itself is bounded to the south by the Transverse Ranges, and to the north by the Klamath Mountains. Offshore the western edge of the continental margin is arbitrarily taken to be the 1,600 fm. (3,000m) contour line, which lies at the foot of the steeper continental slope where it joins the lower declivity of the continental rise. To the north and south the extensive Mendocino and Murray fracture zones are the limits. These major fractures trend from west to east towards the continents from the deep sea oceanic crust. The narrow shelf and steep slope form a distinctive morphological entity, which is clearly different from the continental borderland south of the Transverse Ranges and different from the less steep and somewhat broader shelf and slope north of Cape Mendocino.

The significant features of the northern and central California sea floor are its very narrow shelf with a slope averaging 3°, very steep canyon-cut slope, broad continental rise containing the Delgado and Monterey deep-sea fans, and the broad banks formed on the upper slope west of the Transverse Range and west of San Francisco Bay. The major physiographic divisions of offshore central and northern California are shown in Fig. 35.

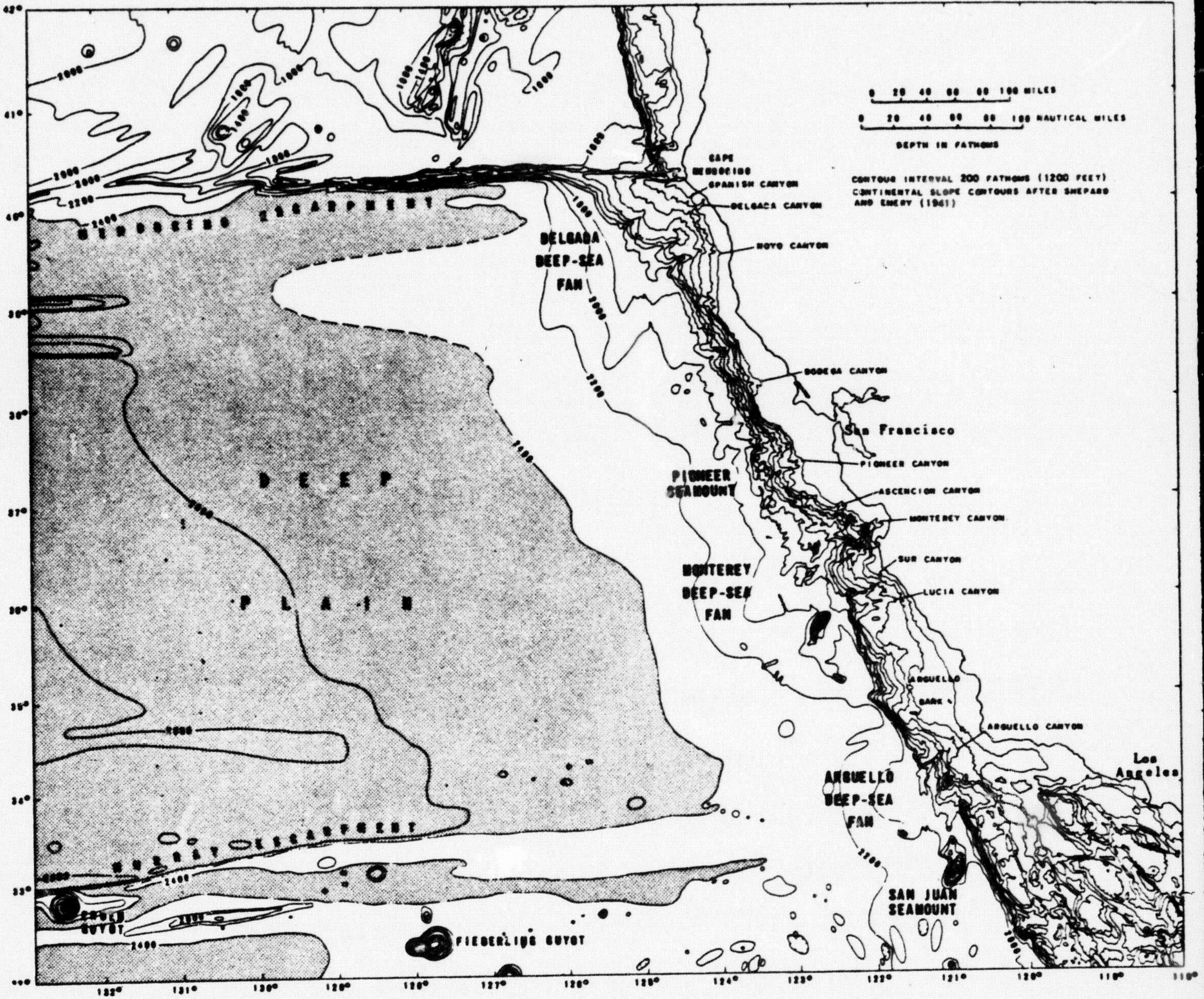

0 20 40 60 80 100 MILES
0 20 40 60 80 100 NAUTICAL MILES
DEPTH IN FATHOMS
CONTOUR INTERVAL 200 FATHOMS (1200 FEET)
CONTINENTAL SLOPE CONTOURS AFTER SHEPARD AND EMERY (1941)
CAPE MENDOCINO
SPANISH CANYON
DELGADA CANYON
NOYO CANYON
BODEGA CANYON
San Francisco
PIONEER CANYON
ASCENCION CANYON
MONTEREY CANYON
SUR CANYON
LUCIA CANYON
ARGUELLO BANK
ARGUELLO CANYON
Los Angeles
DELGADA DEEP-SEA FAN
PIONEER SEAMOUNT
MONTEREY DEEP-SEA FAN
ARGUELLO DEEP-SEA FAN
SAN JUAN SEAMOUNT
MENDOCINO ESCARPMENT
MURRAY ESCARPMENT
DEEP PLAIN
CHOLLA GUYOT
FIEBERLING GUYOT
1000
1200
2000
2200
2400
2600
2800
42°
41°
40°
39°
38°
37°
36°
35°
34°
33°
32°
131°
130°
129°
128°
127°
126°
125°
124°
123°
122°
121°
120°
119°
118°

Figure 35. Principal morphologic features of the sea floor off central California (from Rusnak, 1966; after Shepard and Emery, 1941).

Structrual and Stratigraphical Trends

The continental margin of central and northern California contains six structural basins. These are of late Tertiary age and represent extensions of onshore basins. From south to north these are the Santa Maria, Outer Santa Cruz, Santa Cruz, Bodega, Point Arena, and Eel River Basins (Fig. 36.

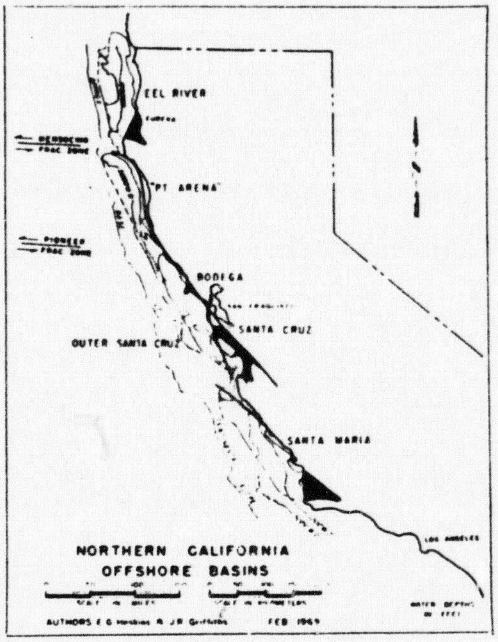

EEL RIVER
MENDOCINO FRAC ZONE
"PT ARENA"
PIONEER FRAC ZONE
BODEGA
SANTA CRUZ
OUTER SANTA CRUZ
SANTA MARIA
LOS ANGELES
NORTHERN CALIFORNIA OFFSHORE BASINS
SCALE IN MILES
SCALE IN KILOMETERS
WATER DEPTHS IN FEET
AUTHORS E.G. Hoskins & J.R. Griffiths
FEB 1969

Figure 36 Location of structural basins offshore central and northern California (from Hoskins and Griffiths, 1971).

Tertiary sections greater than 10,000 feet are found in all basins. The Miocene section is the thickest of the tertiary units.

Santa Maria Basin

The Santa Maria Basin offshore extends from Point Arguello northwest to Point Sur just south of Monterey. It is a shallow post-middle Miocene synclinorium about 140 miles (225km) long and averaging 25-30 miles (40-48km) in width.

Figure 37 shows a section across the Santa Maria Basin.

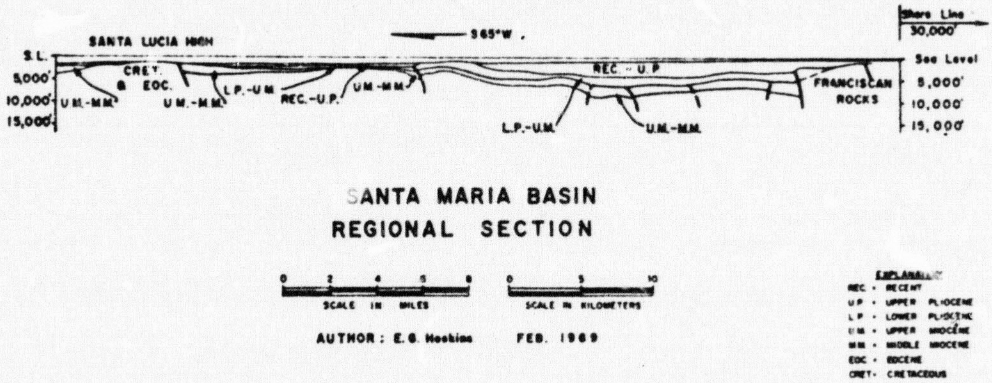

SANTA LUCIA HIGH
S65°W
Shore Line
30,000'
S.L.
5,000'
10,000'
15,000'
Sea Level
5,000'
10,000'
15,000'
CRET. & EOC.
U.M.-M.M.
U.M.-M.M.
L.P.-U.M.
REC.-U.P.
U.M.-M.M.
REC.-U.P.
FRANCISCAN ROCKS
L.P.-U.M.
U.M.-M.M.
SANTA MARIA BASIN
REGIONAL SECTION
0 2 4 6 8
SCALE IN MILES
0 5 10
SCALE IN KILOMETERS
AUTHOR: E.G. Hoskins
FEB. 1969
EXPLANATION
REC. - RECENT
U.P. - UPPER PLIOCENE
L.P. - LOWER PLIOCENE
U.M. - UPPER MIOCENE
M.M. - MIDDLE MIOCENE
EOC. - EOCENE
CRET. - CRETACEOUS

Figure 37. Structure section across the Santa Maria Basin from Grover City to the Santa Lucia High. (from Hoskins and Griffiths, 1971).

Outer Santa Cruz Basin

The Outer Santa Cruz Basin extends northwest from Monterey for 80 miles (130 km) to about 37° 30' N latitude, where it appears to merge with the continental slope. It is a shallow, post-middle Miocene syncline which encompasses approximately 1,400 square miles (3,630) and contains about 1,400 cubic miles (5,830 cu km) of Miocene and younger marine beds. A cross section of the Basin is shown in Figure 38.

1 111

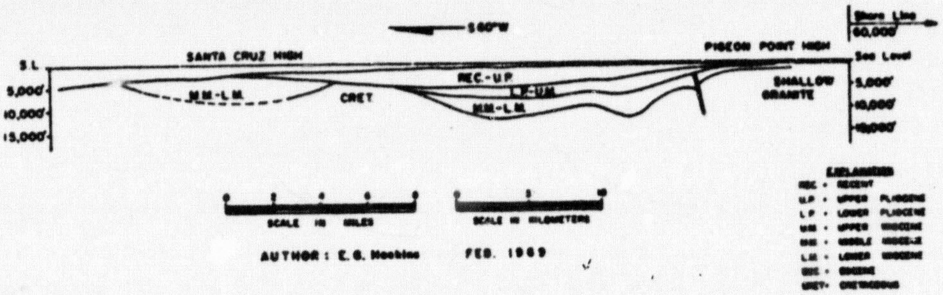

S60°W
Shore Line
60,000'
SANTA CRUZ HIGH
PIGEON POINT HIGH
S.L.
Sea Level
5,000'
10,000'
15,000'
REC-UP
LP-UM
MM-LM
CRET
SHALLOW GRANITE
0 2 4 6 8
SCALE IN MILES
0 5 10
SCALE IN KILOMETERS
AUTHOR : E. G. Hoskins
FEB. 1969
EXPLANATION
REC = RECENT
U.P = UPPER PLIOCENE
L.P = LOWER PLIOCENE
UM = UPPER MIOCENE
MM = MIDDLE MIOCENE
LM = LOWER MIOCENE
EOC = EOCENE
CRET = CRETACEOUS

Figure 38. Structure section across the Outer Santa Cruz Basin from the Pigeon Point High to the Santa Cruz High (from Hoskins and Griffiths, 1971).

The Santa Cruz Basin and the Bodega Basin

The Santa Cruz Basin and the Bodega Basin are contiguous. The Santa Cruz Basin which is bounded on the southwest by the Pigeon Point high and restricted on the northeast by the Montara Granite and the San Andreas fault, encompasses approximately 300 square miles (780 sq. km) and contains about 450 cubic miles (1,875 cu km) of Eocene and younger marine strata. It is considered to be the seaward extension of the Purisima trough.

The Bodega basin is an elongate, shallow late middle Miocene synclinorium which extends offshore from San Francisco to about 38° 45'N latitude. It encompasses an area of about 85 by 17 miles (137 x 27km) and contains on the order of 1,600 cubic miles (6,670 cu km) of Miocene and younger marine strata. A thick section of marine shale and sandstone is present. Large, closed anticlines have been mapped and oil shows have been recorded; water depths are generally less than 600 feet (180m).

Cretaceous granite, which crops out onshore from Point Reyes to Bodega Head and offshore on the Farallon Islands high, is present beneath the Basin and imparts a rigid, block-faulted structural style. Structural cross-sections of the two basins are shown in Fig. 39.

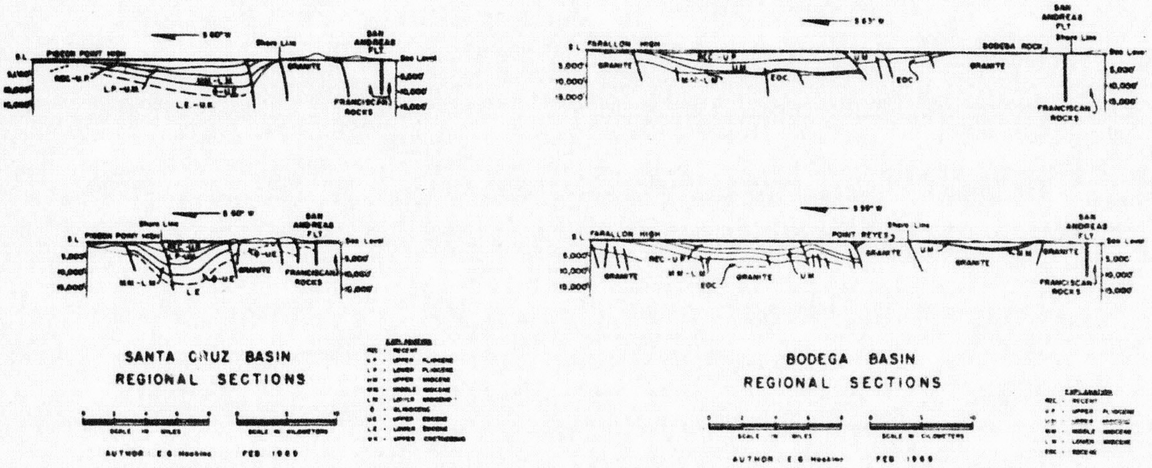

SANTA CRUZ BASIN
REGIONAL SECTIONS
BODEGA BASIN
REGIONAL SECTIONS
SAN ANDREAS FLT
FARALLON HIGH
BODEGA ROCK
POINT REYES
GRANITE
FRANCISCAN ROCKS
Sea Level
Shore Line
5,000'
10,000'
15,000'

Figure 39 . Structure sections for the Santa Cruz and Bodega Basins (from Hoskins and Griffiths, 1971).

Point Arena "Basin"

Point Arena "Basin" does not have a continuous western margin uplift and thus does not constitute a basin of deposition in the same sense as the other five basins discussed. This area is a poorly defined tract bounded on the east by the San Andreas fault, on the west by the approximate upper edge of the continental slope, on the north by the Mendocino fracture zone, and on the south by Point Arena. These boundaries encompass an area of approximately 3,000 square miles (7,770 sq. km) which contains on the order of 3,000 cubic miles (12,500 cu km) of Miocene and younger marine sedimentary rocks.

This area is moderately complex structurally and has several large, untested structures. Oil shows are common in the upper and middle Miocene, and several oil or tar sands crop out onshore at Point Arena.

Pre-Cretaceous metasedimentary rocks underlie at least part of the area, and the southern half shows a structural pattern markedly different from that of the adjacent granite-floored Bodega Basin. A cross-section of the basin is shown in Fig. 40.

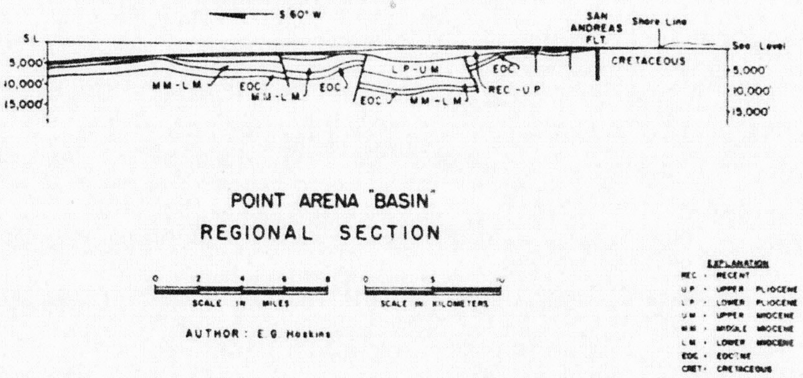

S 60° W
SAN ANDREAS FLT
Shore Line
S L
Sea Level
5,000'
10,000'
15,000'
MM-LM
EOC
MM-LM
EOC
LP-UM
EOC
MM-LM
EOC
REC-UP
CRETACEOUS
5,000'
10,000'
15,000'
POINT ARENA "BASIN"
REGIONAL SECTION
0 2 4 6 8
SCALE IN MILES
0 5 10
SCALE IN KILOMETERS
AUTHOR: E.G. Hoskins
EXPLANATION
REC - RECENT
UP - UPPER PLIOCENE
LP - LOWER PLIOCENE
UM - UPPER MIOCENE
MM - MIDDLE MIOCENE
LM - LOWER MIOCENE
EOC - EOCENE
CRET - CRETACEOUS

Figure 40 . Structure section of the Point Arena "Basin" (from Hoskins and Griffiths, 1971).

Eel River Basin

Of the six basins described, the Eel River is the largest in areal extent and possibly in volume of marine strata. It extends from False Cape, south of Eureka, north into Oregon to about Cape Sebastian, a length of approximately 130 miles (210 km). The basinal outline encloses an area of 4,000 square miles (10,360 sq. km), which contains an estimated 7,000 cubic miles (29,170 cu km) of marine Miocene and younger strata.

The main structural features in the basin are nearly parallel with its long axis, which has a west-northwest trend onshore and swings to a north trend offshore, Folds onshore, including the productive Table Bluff and Tompkins Hill anticlines, appear to be at least partly due to compressional buckling associated with the uplift of the present basin margins. Several folds and faults offshore display an en echelon relation which suggests horizontal shear forces. Structural sections of the Eel River Basin are shown in Fig. 41.

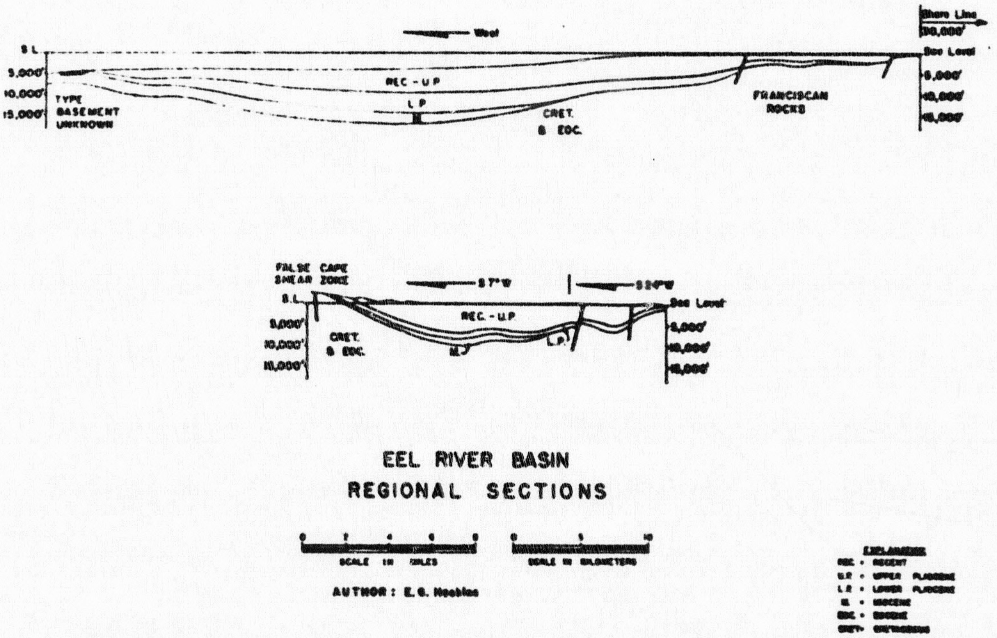

West
Shore Line
30,000'
S.L.
5,000'
10,000'
15,000'
TYPE BASEMENT UNKNOWN
REC.-U.P.
L.P.
CRET. & EOC.
FRANCISCAN ROCKS
Sea Level
5,000'
10,000'
15,000'
FALSE CAPE SHEAR ZONE
S 7° W
S 24° W
S.L.
5,000'
10,000'
15,000'
CRET. & EOC.
REC.-U.P.
M.
L.P.
Sea Level
5,000'
10,000'
15,000'
EEL RIVER BASIN
REGIONAL SECTIONS
0 2 4 6 8
SCALE IN MILES
0 5 10
SCALE IN KILOMETERS
AUTHOR : E. G. Hoskins
EXPLANATION
REC. - RECENT
U.P. - UPPER PLIOCENE
L.P. - LOWER PLIOCENE
M. - MIOCENE
EOC. - EOCENE
CRET. - CRETACEOUS

Figure 41. Structure sections across the Eel River Basin (from Hoskins and Griffiths, 1971).

(b) Hydrocarbon Potential

The offshore Santa Maria Basin seems to represent an excellent continuation of onshore stratigraphic, lithologic and structural trends. Onshore production has been primarily from fractured Miocene shales and, to a lesser extent, fine-grained lenticular Pliocene sands. Cumulative petroleum production (to 1-73) of 609 million bbl. had been achieved by dense exploratory drilling, close spacing of wells in known fields and expensive well treatments, due to the low gravity (high density) nature of the crude.

Potential reservoir strata are limited in the southeastern one-third of the basin while most of the remaining area is characterized by a thin, poorly-known Tertiary section and water depths commonly exceeding 450 meters.

Hydrocarbon shows onshore Bodega and Santa Cruz Basins have not been significant. The more promising potential reservoir strata and structural traps have already been tested and results suggest that these sections have low hydrocarbon potential.

Eel River Basin contains numerous large structural traps and a potentially thick marine shale section. Indications of local shale flowage and diapirism are also present. Miocene marine clastic strata extend offshore and probably contain reservoir-quality sandstone. Pre-Miocene strata appear to have poor petroleum potential. Onshore production has yielded 56 BCF of gas from thin, lenticular and very fine-grained Pliocene sands, along with minor quantities of oil from the Mesozoic. Equating onshore gas production to oil at 5.6 MCF/bbl., gives an equivalent value of 10 million bbl. of oil.

Only limited hydrocarbon shows have been found offshore. The Eel River Basin, although largely untested, appears to have some hydrocarbon potential, particularly for gas. Economically attractive offshore strata however, lie mainly beneath the western two-thirds of the basin where water depths exceed 460 meters.

(c) Geological Hazards

A general discussion of potential geologic hazards offshore California is included in section II.A.3.a.(1)(c).

(3) Washington-Oregon Pacific OCS

(a) General

The continental margin off Oregon and Washington represents the western part of a Tertiary depositional trough that trended north-south from what is now Vancouver to the Klamath Mountains. Width of the trough extended from the Cascade Mountains on the east to near the base of the present continental slope on the west. Two prominant subsea features, the Cobb and Blanco Fracture Zones represent approximate natural offshore boundaries on the north and south, respectively (Fig. 42).

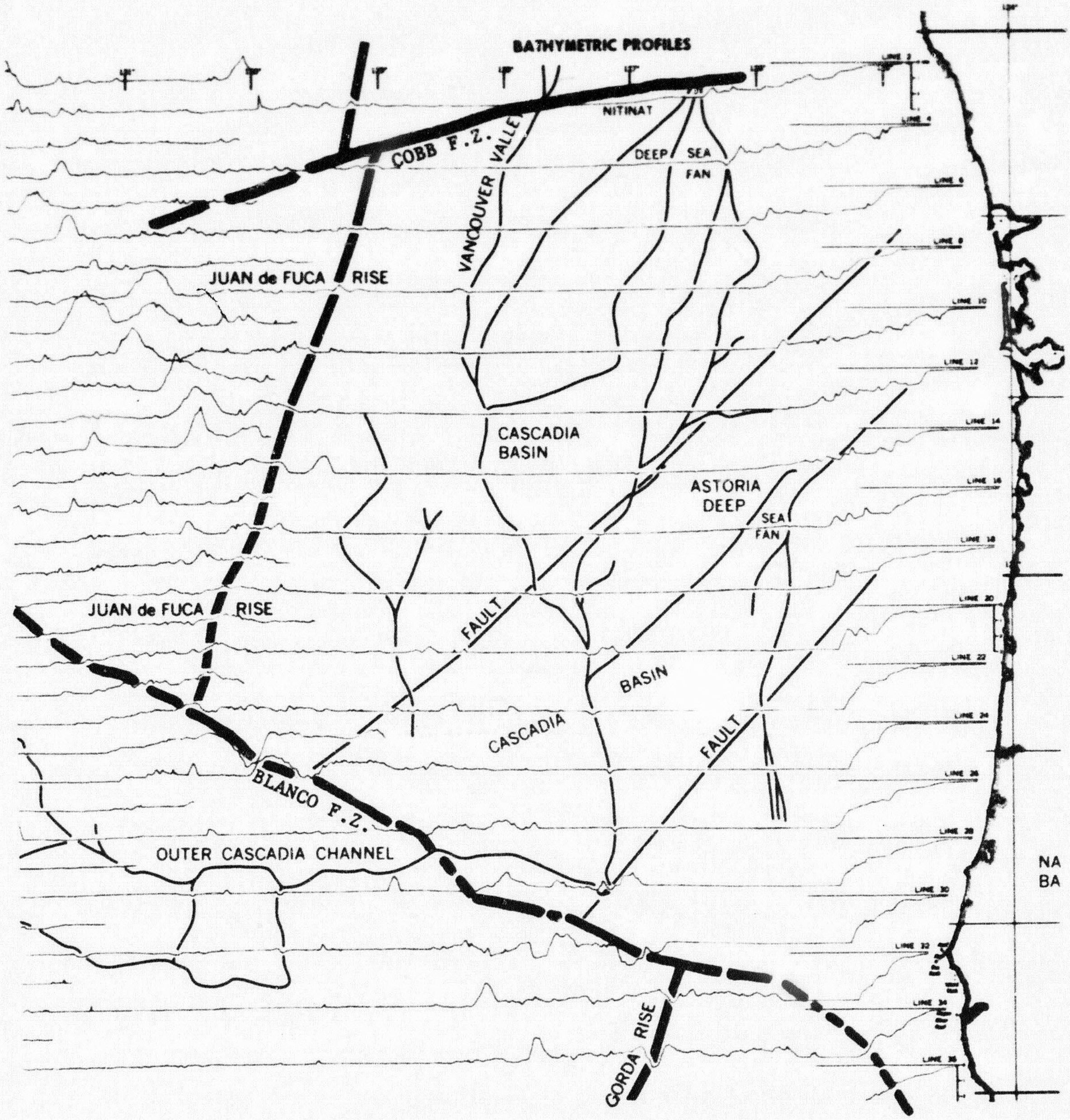

BATHYMETRIC PROFILES
COBB F.Z.
NITINAT
DEEP SEA FAN
VANCOUVER VALLEY
JUAN de FUCA RISE
CASCADIA BASIN
ASTORIA DEEP
SEA FAN
FAULT
JUAN de FUCA RISE
CASCADIA BASIN
FAULT
BLANCO F.Z.
OUTER CASCADIA CHANNEL
GORDA RISE
NA
BA
LINE 2
LINE 4
LINE 6
LINE 8
LINE 10
LINE 12
LINE 14
LINE 16
LINE 18
LINE 20
LINE 22
LINE 24
LINE 26
LINE 28
LINE 30
LINE 32
LINE 34
LINE 36

Fig 42. Geomorphic Features of the offshore Oregon and Washington area.

Oldest rocks in the depositional basin are early Eocene volcanics which form the effective basement, or subsurface boundary upon which potential oil and gas strata may lie. The entire Tertiary basin sequence is thought to overlie oceanic crust although late Cretaceous deposits exposed along the southern margin may be present within the trough as well. Within the basin, the middle to late Tertiary section generally consists of a marine sandstone and siltstone sequence up to 25,000 feet thick, with occasional interbedded volcanic and non-marine rocks. Drilling offshore central Oregon has penetrated over 12,000 feet of rock dating from late Eocene to recent (Figs. 43 and 44). In view of the limited well data and thick overburden of Holocene sediments, estimates on the nature and distribution of the Tertiary strata offshore Washington are largely speculative.

The depositional history of this structural province has been complicated by periodic submarine, subaerial and deep-seated volcanism accompanied by several phases of tectonic uplift and subsequent erosion. The latest period of major crustal uplift, which occurred during the late Tertiary and early Quaternary periods, elevated the thick Tertiary sedimentary section into what is now the Coast Range. Structurally, the Coast Range is a broad anticlinorium, or regional upwarp, that consists of numerous alternating structural ridges and troughs. These folds continue offshore where some of the ridges appear to be actively growing, involve Quaternary strata and form

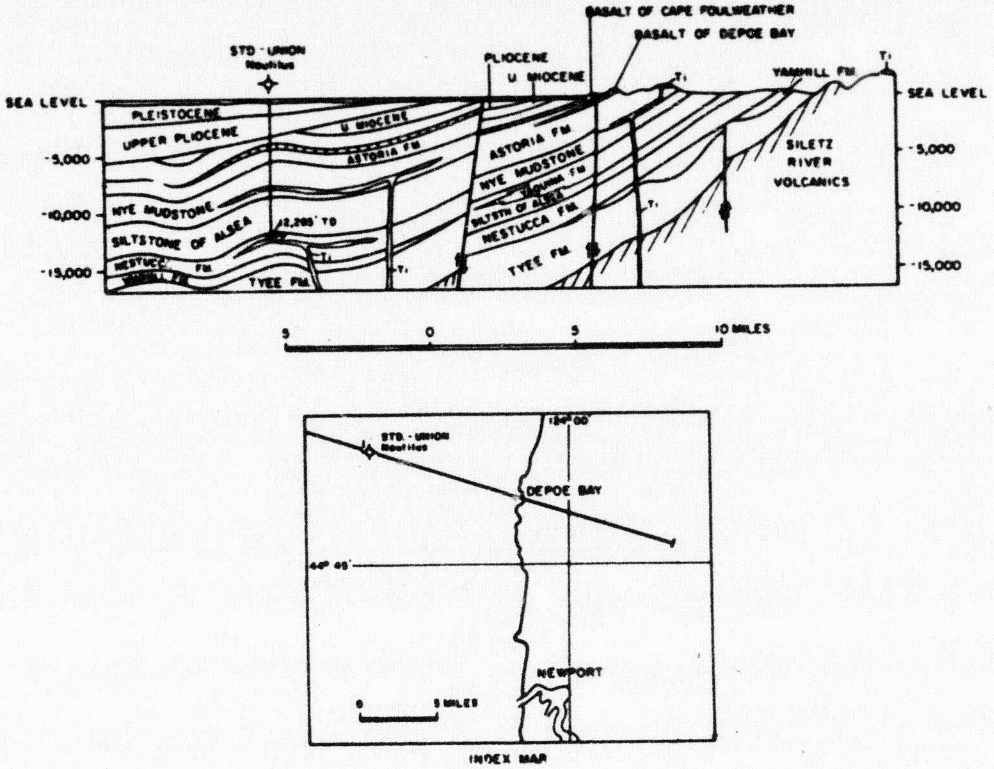

BASALT OF CAPE FOULWEATHER
BASALT OF DEPOE BAY
STD - UNION Nautilus
PLIOCENE
U MIOCENE
YAMHILL FM
SEA LEVEL
PLEISTOCENE
UPPER PLIOCENE
U MIOCENE
ASTORIA FM
NYE MUDSTONE
SILTSTONE OF ALSEA
12,205' TD
NESTUCCA FM
YAMHILL FM
TYEE FM
YAQUINA FM
NESTUCCA FM
SILETZ RIVER VOLCANICS
-5,000
-10,000
-15,000
5 0 5 10 MILES
124° 00'
DEPOE BAY
44° 45'
NEWPORT
0 5 MILES
INDEX MAP

Fig. 43. -Cross section from central Coast Range to continental shelf of Oregon near lat. 44°45'N.

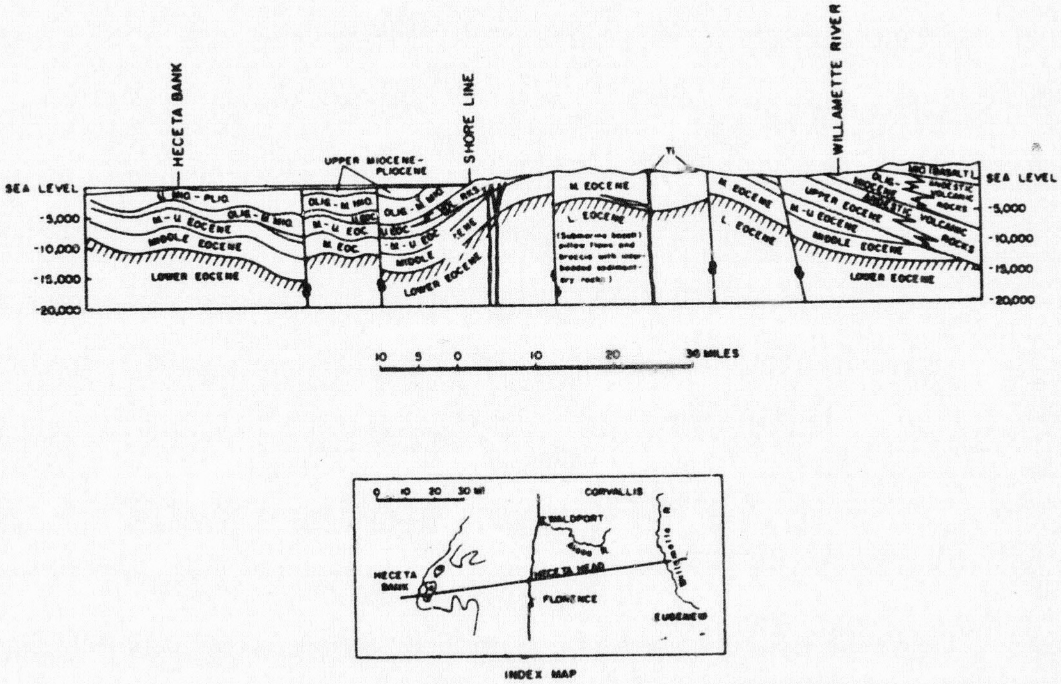

HECETA BANK
SHORE LINE
WILLAMETTE RIVER
UPPER MIOCENE-PLIOCENE
SEA LEVEL
U MIO - PLIO
OLIG - M MIO
M - U EOCENE
MIDDLE EOCENE
LOWER EOCENE
M - U EOC
M EOC
M EOCENE
L EOCENE
(Submarine basalt pillow flows and breccia with interbedded sedimentary rocks)
UPPER EOCENE
OLIG - MIOCENE ANDESITIC VOLCANIC ROCKS
MIO (BASALT)
-5,000
-10,000
-15,000
-20,000
10 5 0 10 20 30 MILES
0 10 20 30 MI
CORVALLIS
WALDPORT
HECETA BANK
HECETA HEAD
FLORENCE
EUGENE
INDEX MAP

Fig. 44 -Diagrammatic cross section from Willamette Valley to continental shelf of Oregon near lat. 44°N.

(from Braislin, et al., 1971).

bathymetric highs. The late Tertiary strata are cut by numerous shale diapirs on the Washington and western half of the Oregon continental margin.

Oil and Gas Seeps

Oil and gas seeps have been reported from the coastal area of the Olympia Peninsula of Washington. These seeps along with petroliferous rich muds known as the "smell muds" are the only reports of natural seepage found. The smell muds are found in the vicinity of the mouth of the Hoh River as well as further north along the coast.

(b) Hydrocarbon Potential

Although hydrocarbon production onshore Oregon and Washington has not been commercially significant, the thicker late Tertiary sequence found offshore may hold more promise. Mid to late Tertiary sandstone strata which outcrop onshore are probable well represented beneath the continental shelf. Limited offshore drilling and seismic data have revealed diapiric shale offshore Washington and northern Oregon. In general, these data suggest that structural and stratigraphic trapping potential is good in the areas surveyed.

A realistic appraisal of hydrocarbon potential in this OCS area, however, must await the accumulation of additional geophysical and test drill data.

(c) Geologic Hazards

Data about geologic hazards in Oregon and Washington is very limited. However, a survey of existing literature revealed material concerning earthquakes, mass wasting and floods. These are discussed below.

Earthquakes

Both Washington and Oregon have histories of earthquake occurrence. In Washington, the majority of quakes were centered in the vicinity of Seattle, Tacoma and Olympia where numerous earthquakes, some with intensities as high as VIII on the Mercalli Scale have been reported. Coastal Washington has experienced very few earthquakes with only a handful recorded from Clallam and Grays Harbor Counties.

Oregon is very similar to Washington in having a history of earthquakes but no major destruction. All of Oregon's coastal counties have reported earthquakes. Couch and Lowell (1971) compute that the Coast Range of Oregon will have one 5.0 magnitude earthquake each decade. Lincoln County has had seven quakes during a 70-year period ending in 1967. Four of these were centered at Newport (maximum intensity IV).

Mass Wasting

Both the Oregon and Washington coastlines have areas subject to landsliding and slumping.

In Oregon, coastal outcrops of the Nestucca, Astoria and Nye formations as well as bedded volcanic rocks are frequently the locale for slumps and slides. Most of these occur as slides along bedding planes which dip towards the sea (Oregon Dept. of Geology and Mineral Industries, 1973). Washington's coastal area also is the location of units which dip towards the sea. Many active slides and slumps are known from the Hoh Rock Assemblage of the central Washington coastal area.

Flooding

The coastal ranges of Oregon and Washington are centers of high precipitation. Rainfall of up to 100 inches per year causes widespread spring and fall flooding. The Columbia, Siletz, Umpqua and many other rivers have flooded during historic time. The 1894 flood of the Columbia River had a maximum discharge of over 1.2 million c.f.s. Lowland flooding produces many mudflows along areas with gradients.

b. Climate

(1) General Climatology and Seasonal Weather Patterns

The climatology of the Pacific Coast is influenced chiefly by the location and intensity of the Pacific high and Aleutian low pressure systems. The former system, located off southern California around 140° to 150° W. longitude, is a fairly stable system throughout the year. The Aleutian low is a much more transient system with variable intensity. The gradient between these two systems determines the direction and strength of winds and weather systems off the Pacific coast.

During the summer months, the Aleutian low is almost non-existent, resulting in no gradient between the two oceanic systems. However, a gradient does form between the oceanic system and a continental low pressure center. Consequently, moderate winds, predominantly from the north and northwest occur along the entire Pacific coast. For the most part, these winds bring cool moist air onshore, often forming fog along the coast.

In the fall the Aleutian low begins developing over the Gulf of Alaska and Bering Sea. Winds increase in velocity and blow from the southwest and west. Along the coast from northern California to British Columbia, low pressure storm systems pulse onshore from the west almost continuously throughout the winter, bringing rain and cool temperatures. Along the southern California coast most winter storms are shunted to the north by the high pressure system offshore. Winds are light, rain showers are few, and days are generally sunny and relatively warm.

The Aleutian low gradually weakens during the spring. Storms become less frequent and pass farther north over the continent. As summer progresses, daily atmospheric pressure fluctuations become much smaller in magnitude and the winds begin shifting to the north and northwest.

(2) Sky Cover and Visibility

Two meteorological phenomena, clouds and fog, are responsible for variations of sky cover and visibility. The distinction between clouds (associated with storm fronts) and fog (associated with near-surface local effects) is often neglected because of their similarity. The distinction is important for offshore operations where fog is less frequent than in coastal land areas.

In general, cloud cover increases in the northern latitudes, both in areal extent and duration. Cloud cover is about 10 to 20% greater off northern California than off southern California. Mean annual sky cover, 40-60% in California, to 60-80% off Oregon and Washington (U.S. Dept. of Commerce, 1968). April, May and June are among the cloudiest months along the Pacific coast States. As summer approaches, clouds recede during the day as solar heating becomes dominant.

Fog is common along the Pacific coast. This is the result of warm moist air from offshore moving over the cold upwelled water along the coast. The seaward extent of fog is variable, depending on the extent of cold coastal water and numerous other conditions. Fog can range from a few hundred yards to hundreds of miles offshore (U.S. Dept. of Commerce, 1968a).

(3) Surface Wind Patterns

Wind patterns along the Pacific coast are the result of atmospheric pressure systems discussed in the climatological section above. Summer winds from the north and northwest have average velocities ranging from 6 to 14 knots. Winter winds from the south and southwest have average velocities of 6 to 10 knots (U.S. Dept. of Commerce, 1961). Average wind velocities are somewhat misleading, particularly during the winter months, when gales (>34 knots) are frequent along the northern portion of the Pacific coast. Winter gales accompany about 5 to 8% of the storms crossing the northern Pacific coast, while only 1% of the storms off southern California are accompanied by gales. These winds are invariably from the south. Along the southern California coast (south of 35°N.), gales are very frequent, with no predominating direction (U.S. Dept. of Commerce, 1968a). Summer gales occur but with considerably less frequency.

Superimposed on the basic north-south flow of winds are the local onshore-offshore sea breezes. These diurnal (occurring daily) winds develop from unequal heating and cooling of the ocean and adjacent land mass. As the land is heated, the air above rises, creating an area of low pressure. This induces the cooler air over the ocean to flow onshore throughout the day. At night, thermal conditions are reversed, resulting in weak offshore breezes in the early morning.

Velocities of sea breezes are generally in the range of 15 to 20 knots (Allan Hancock Found., 1965). These winds in themselves do not constitute a hazard, but may intensify a major storm system in the area. Depending on the location, season, and weather conditions, the effect of the sea breeze may extend far offshore.

(4) Air Temperature

Air temperatures along the Pacific coast are controlled by the marine environment. The ocean, with its high specific heat (the amount of heat required to raise the temperature of 1 g. of water 1°C.), acts as a heat reservoir to damp out daily and seasonal oscillations of temperature. Days are cool and nights are relatively warm. Air temperature variations occur slowly, and extreme variations are seldom experienced.

Temperature recorded at various coastal areas are useful for illustrating the differences along the coast. The U.S. Dept. of Commerce (1968a) gave several thermal descriptions for Pacific coastal locations as shown in Table 9.

TABLE 9.

TEMPERATURE RANGES (°F) FOR FOUR PACIFIC COAST CITIES

	Los Angeles	San Francisco	Eureka (Calif.)	Astoria (Oregon)
Highest temperature	90	79	77	65
Normal Maximum	64	55	54	47
Normal Average	54	49	47	41
Normal Minimum	45	42	41	35
Lowest Temperature	28	29	20	14

Offshore air temperatures are generally warmer than the adjacent coastal temperatures. Mean maximum temperatures in the summer off southern California are about 10° higher offshore, and about 15° higher during the winter (SCOSC, 1974). Similar differences occur in more northern waters. Although this suggests that freezing air temperatures never occur offshore, polar air masses from the continent may move short distances offshore at times during the winter.

(5) Precipitation

Precipitation along the entire Pacific coast occurs predominantly from late fall through early spring. The amount of yearly rainfall increases as one moves south to north (Fig. 45). The Washington coast receives nearly five times as much precipitation annually as the southern California coast. This large difference between regions illustrates the influence of the Pacific high pressure system which causes winter storms to be deflected onto the Oregon and Washington coasts.

Elliott and Reed (1973) showed that precipitation offshore was only about one-half to one-third of that found at coastal land stations along the north Pacific coast. Their preliminary results indicate offshore rainfall may also be considerably less than precipitation recorded at California coastal land stations.

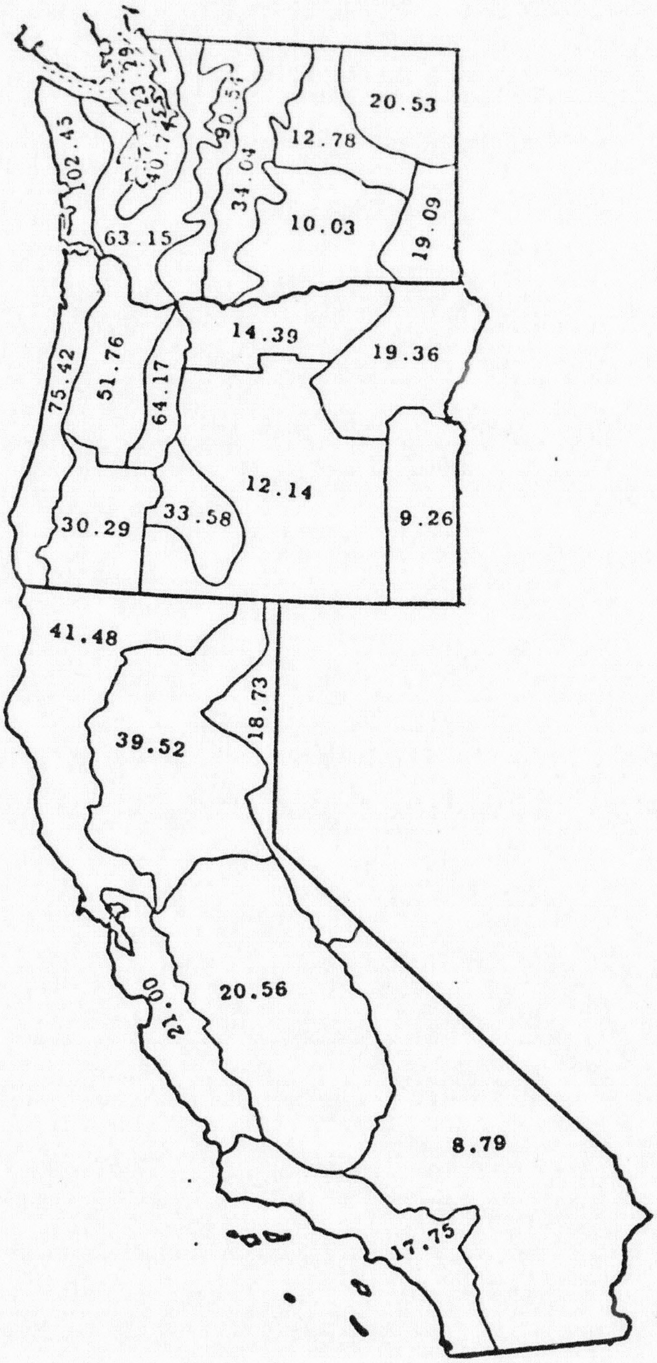

20.53
12.78
10.03
19.09
102.43
40.74
23
29
90.54
34.04
63.15
14.39
19.36
75.42
51.76
64.17
12.14
9.26
30.29
33.58
41.48
18.73
39.52
20.56
21.00
8.79
17.75

Figure 45. Mean Annual Total Precipitation (inches) for California, Oregon and Washington. From U.S. Dept. of Commerce (1968a).

(6) Storms

Storms which occur along the Pacific coast are almost invaribly associated with the movements and changes in intensity of the Pacific high pressure system. As the system weakens or moves to the south, low pressure systems from various locations move closer to the Pacific coastal States bringing winds and sometimes rain with them. There are three primary geographical locations which generate storms which affect the Pacific coastal areas (Allan Hancock Found., 1965). These are: 1) the southern Gulf of Alaska, 2) northern boundary of the Pacific high, and 3) tropical hurricane latitudes.

The first two areas produce storms with winds, occasionally of gale force, which approach the Oregon, Washington and northern California coasts from the southwest. The central and southern California coast is usually not affected by these storms, which prevail throughout the winter months.

Extratropical cyclones, associated with the northern boundary of the Pacific high pressure system, generally approach from the west. Winds may also be from the northwest or southwest, depending on the locations of the storm center and the Pacific high pressure system.

Tropical hurricanes rarely strike the Pacific coast north of Baja, Mexico. The few that do can be very destructive. One such storm occurred in 1939 with winds of 60 knots. Damage in Los Angeles from this storm was estimated at $1,500,000 (SCOSC, 1974). The principal effects of tropical hurricanes in California are the peripheral winds and swell that reach the coastline.

Thunderstorms are very infrequent along the Pacific coast. In fact, the Pacific States normally experience fewer electrical storms than any other region of the United States (U.S.G.S., 1974). Thunderstorms occur most frequently from late fall through early spring. Along the Oregon and Washington coasts, about eight thunderstorms develop per year, while San Francisco averages about two per year (U.S. Dept. of Commerce, 1968a).

c. Physical Oceanography

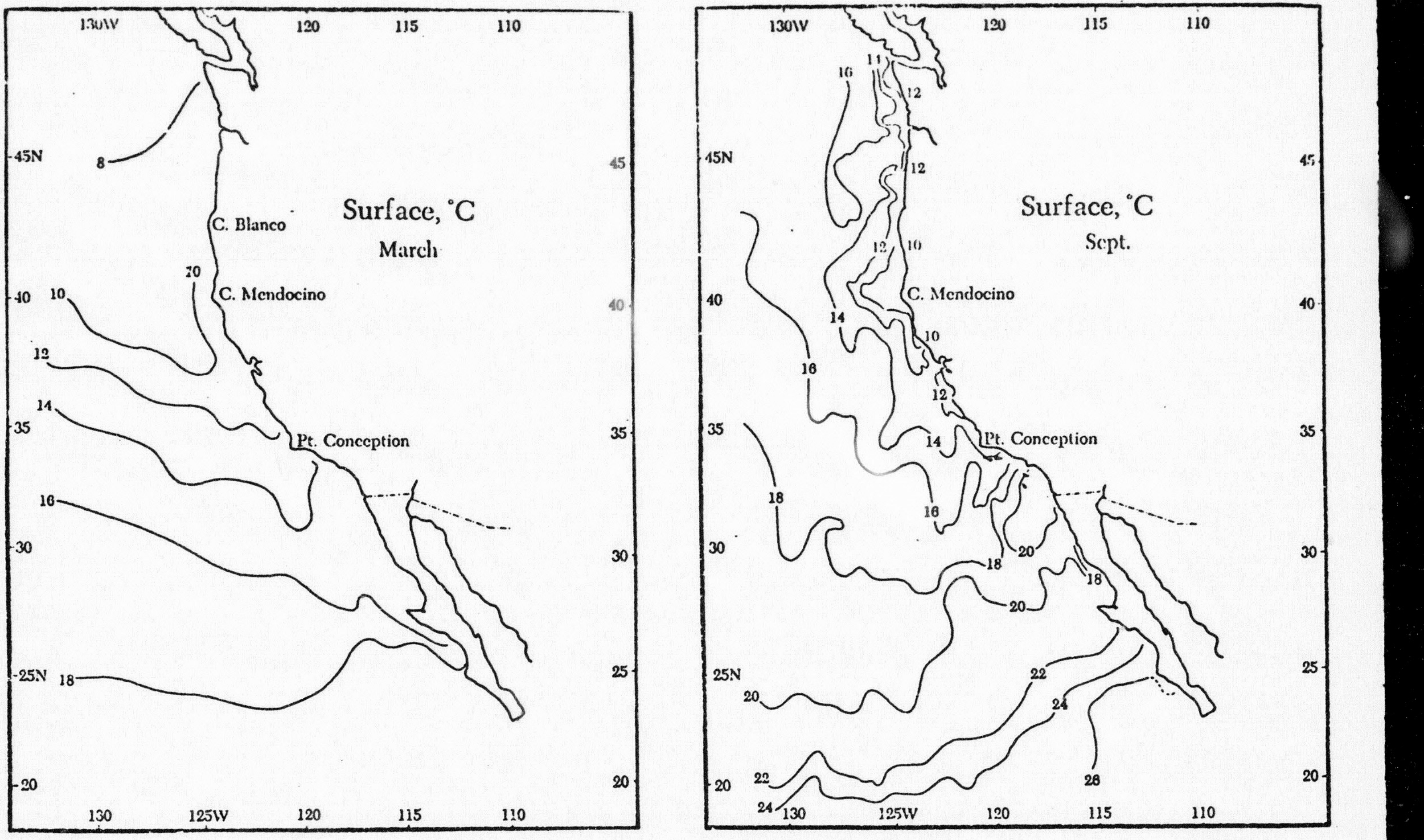
(1) Surface Sea Temperatures

Surface sea temperatures off the Pacific coast reflect ocean circulation and wind conditions. During the summer, northern winds induce a southerly flowing current. As the earth rotates under this current, there is a net transport of water to the west. In turn, cold water from the depths moves up to the surface and replaces the westerly transported water. This upwelling is most pronounced during the spring and summer, causing pockets of cold water (10° to 12°C.) along the coast from central California north to Washington (Fig. 46b). Terrestrial runoff and upwelling effectively "push" these cooler water masses into the 14°C. water farther offshore. The warmest continental shelf waters (20°C.) occur off San Diego (Fig. 46b).

The Columbia River plume off Oregon and northern California modifies sea surface temperatures to some extent in the early summer. The plume is a thin (down to 20 meters) layer of somewhat fresher, hence less dense water which remains at the surface and resists vertical mixing. This layer is gradually heated by the sun and may be several degrees warmer than adjacent offshore waters (Pearcy and Keene, 1974).

In winter and early spring, cold waters near the shore are shifted north and offshore as a relatively warm northward current (Davidson Current) develops near shore (Fig 46a). This northward current appears to be the result of a weakening of the southward surface current, and is reinforced by southerly winds.

Warmest waters of the Pacific coast occur off southern California in all seasons. Temperatures range from 15°C. in the winter to 20°C. in the summer. By comparison, temperatures off Washington range from 8°C. in the winter to 16°C. in the summer.


130W
120
115
110
45N
45
40
35
30
25N
25
20
130
125W
8
10
12
14
16
18
C. Blanco
C. Mendocino
Pt. Conception
Surface, °C
March
130W
120
115
110
45N
45
40
35
30
25N
25
20
130
125W
10
11
12
14
16
18
20
22
24
28
C. Mendocino
Pt. Conception
Surface, °C
Sept.

a.

b.

Figure 46 . Smoothed isotherms for winter and summer surface temperatures in the eastern Pacific Ocean (From Ricketts, et al., 1968).

(2) Salinity

Surface (0-10 meters) salinities of the Pacific offshore areas range from about 33°/oo to 34°/oo. Variations occur where major rivers flow into the sea and where summer upwelling is intense. Salinity differences are largest during the summer months, when maximum runoff and upwelling occur. Salinities in winter are fairly consistent along the entire coast, with a gradual decrease towards the northern latitudes.

In the summer, there appears to be a salinity regime composed of three rather distinct zones. Nearshore salinities off California are about 33.8°/oo, due to the upwelling process which brings cold, saline water up from the depths. Beyond this zone of upwelling, salinities decrease somewhat (33.4°/oo), representing cool subarctic surface waters carried south by the California Current. The third zone, several hundred miles from shore, exhibits the highest salinities (33.8°/oo). This water is away from the influence of runoff and ice melt. Evaporation exceeds precipitation thus increasing the salinity.

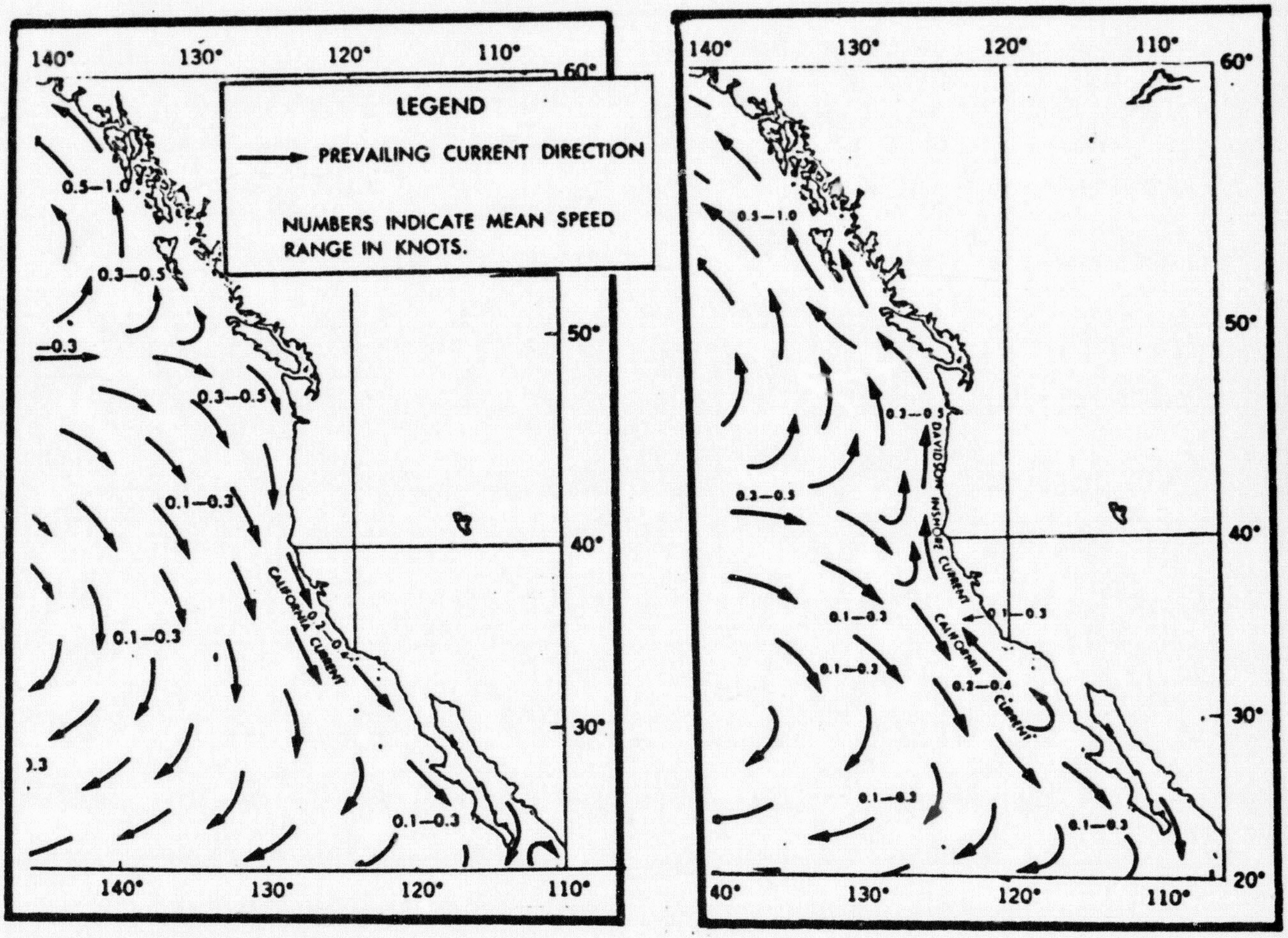
Barnes, et al. (1972) examined the oceanic areal and seasonal distribution of the Columbia River discharge off Oregon and Washington. This freshwater flow into the ocean has a considerable effect on the salinity distribution. A large, low-salinity plume (32.5°/oo) extends over 200 miles to the southwest of the river mouth during the summer. Essentially, this enhances the three-zone salinity regime discussed above, in that the middle zone is considerably fresher off Oregon and northern California than off southern California.

During the winter months the flow of the Columbia River is greatly reduced. Its discharge moves northward along the Washington coast under the influence of the prevailing southerly winds and the Davidson Current.

(3) Surface Circulation

Water of the north Pacific Ocean is driven eastward by the prevailing westerly winds until it encounters the North American Continent (Fig. 47). At approximately 45°N. latitude (about 50° in the summer; 43° in the winter) the flow branches into the northward Alaska Current and the southward California Current. (For reference, the Columbia River mouth is about 46°N. latitude). The offshore waters of Washington lie on the southern margin of the Alaska Current during the winter months, but this current has little influence here because of its transitional state, low speed, and the effects of local weather conditions.

The California Current is a meandering, diffuse, variable, and poorly defined flow easily influenced by the wind (Boisvert, 1969). It is a shallow current, with more than 90% of the transport above 300 meters (Sverdrup, et al., 1942). The resultant direction is south, roughly parallel to the coastline. Velocities along the coast (within 60


LEGEND
PREVAILING CURRENT DIRECTION
NUMBERS INDICATE MEAN SPEED RANGE IN KNOTS.
140°
130°
120°
110°
60°
50°
40°
30°
20°
0.5—1.0
0.3—0.5
0.3
0.1—0.3
0.2—0.4
CALIFORNIA CURRENT
DAVIDSON INSHORE CURRENT

SUMMER

WINTER

Figure 47 Surface circulation along the U.S. Pacific coast. Adapted from U.S. Dept. of Commerce (1961).

miles) are usually less than 0.5 knots, and are somewhat higher than those reported farther offshore (U.S. Dept. of Commerce, 1961).

Variations in direction and speed of the California Current are common. However, there are two well-known and semi-permanent current patterns which are of importance. These are the Southern California Countercurrent and the Davidson Current. The former current forms in the summer months along the Southern California-Mexican border. Part of the California Current is deflected to the east at this point and flows to the north into the Santa Barbara Channel, thus creating a large gyre or eddy. At the northern end of the Channel, water flows out to rejoin the California Current, or continues inshore of the Channel Islands to complete the gyre. During the winter months the Southern California Countercurrent becomes nearly indistinct from the flow of the Davidson Current.

The Davidson Current is strictly a winter occurrence from the tip of Baja California to about 50° N. latitude (Fig. 47). Like the California Current, the Davidson Current is sporadic and ill-defined dependent mainly on the influence of the wind (Boisvert, 1969). The flow is confined to a narrow zone along the continental margin. It is thought to be a vertical extension of the northward flowing undercurrent in this region (Reid, et al., 1958). Current speeds generally average about 0.5 knots.

(4) Tides

The tides along the Pacific coast are classified as semi-diurnal and mixed. This implies that the sea level rises and falls twice each lunar day (24.84 hours) and that successive high (or low) water levels are not equal. The magnitude of the inequality depends primarily on the declination of the moon (angle between the moon and the north-south axis of the earth). The greatest inequalities occur when the moon is at its maximal north or south declination.

Along the outer Pacific coast, the average high tide exceeds the low tide by about 5 feet off southern California, and about 7.5 feet off the coast of Washington (U.S. Dept. of Commerce, 1968a). Extreme variations of 10 to 14 feet may occur once a year, usually in December when the sun is closest to the earth. Although the sun's influence on the tides is not as great as the moon's, it is at this time that the maximal combined gravitational attraction occurs.

The tides may be considered as a very long "wave", with the high and low tide corresponding to the wave crest and wave trough, respectively. The crest moves along the Pacific coast from the south to the north, such that high water off Washington occurs three to four hours after high water in southern California.

Local variations in coastal topography play an important part in determining the actual tide height at any specific location. Coastal bays, narrows, and estuaries tend to "funnel" the tide, resulting in higher than expected water levels. For example, in Alaska's Bristol Bay, Amak Island experiences a mean tide range of about 5 feet, while in the Naknek River entrance, at the apex of the Bay, tides reach about 18 feet (U.S. Dept. of Commerce, 1971a). These stations are both located in Bristol Bay and are about 300 miles apart. Such extreme tides are not present from southern California to Washington.

Accompanying the rise and fall of the tide are substantial horizontal movements of the sea known as tidal currents. In general, the larger the vertical tide range, the stronger the tidal currents. Because offshore tidal heights are very small (usually less than one foot), offshore currents are likewise of little significance. Velocities range from 0.4 knots off San Francisco to 0.9 knots at Swiftsure Bank (Washington), as indicated by measurements from offshore lightships (U.S. Dept. of Commerce, 1971b).

(5) Sea and Swell

Sea refers to the waves generated locally in an area, while swell refers to the waves generated in a distant region and traveling through an observation point. Sea tends to be choppy and irregular, whereas swell waves tend to have lower crests and are more regular and symmetrical.

Wave conditions off the Pacific coast reflect the prevailing wind condtions to a large extent. (The wind regime has been discussed previously.)

However, swell may arrive at the Pacific coast from distant storms in the Gulf of Alaska, the central North Pacific, and the southern Pacific Ocean. The two former locations generate swell most often in the winter months while the swell from the southern Pacific occurs most frequently during the summer months of the northern hemisphere (austral winter). Rough sea conditions occur most frequently during the stormy months of winter.

A comparison of sea and swell roses for the U.S. Pacific coast (U.S. Dept. of Comm., 1970) indicates several general conclusions. The most important are: sea waves generated by local storms are generally higher than the wave heights of swell; the highest waves occur in the winter, and arrive from south and southwest; seas and swell off Oregon and Washington tend to be respectively greater in winter and calmer in summer than off California.

The above conclusions are very general and do not reflect wave modification or amplification that occurs by local topography, such as promontory points, canyons and river mouths. Furthermore, wave observations are derived primarily from ship reports which are biased toward good-weather shipping routes. North Pacific storms can be severe; a 95-foot wave has been recorded from an offshore drilling platform in this area (Ocean Industry, 1969).

(6) Tsunamis (Seismic Sea Waves)

Tsunamis are usually generated by submarine earthquakes or volcanic eruptions. Generally they are long-period waves (from 5 minutes to several hours), low in height (a few feet or less) and may travel at speeds well over 400 knots. On the open sea in deep water, they have a low height and a tsunami will usually go unnoticed by ships at sea. However, as the wave moves over shallow water a wave with large height may form, modified by coastal and bottom configurations. Most of the damage occurs at this point, often in the form of rapidly rising water levels or bores rather than breaking waves.

According to the Coast Pilot #7 (1968), the coasts of California, Oregon and Washington are not generally subject to waves of the magnitude which strike the Hawaiian Islands and other Pacific areas, although widespread damage to moored ships and to waterfront areas occurs occasionally. The wave of May 23, 1960, originating off the Chilean coast, caused several hundred thousand dollars damage to ships and docking facilities in the Los Angeles area alone. Much of the damage in the Los Angeles area during the 1960 wave was caused by rapid currents and the swift rise and fall of the water level which broke mooring lines and set floating docks and ships adrift.

d. The Biological Environment

The most commonly accepted biological zonation of the continental United States Pacific coast region is a division into northerly Oregonian biota and southerly Californian biota with the division occurring around Point Conception, California (35°N. latitude). Within a few degrees north and south of this point there are several endemic (native) species as well as a mixture of northern and southern species.

(1) Phytoplankton

Phytoplankton is the "grass" of the sea, the primary producers upon which the marine food chain is ultimately based. Waters of the Pacific coast have very large quantities of phytoplankton, especially during spring and summer. These seasons are periods of coastal upwelling and terrestrial runoff which act to replenish nutrients to the surface waters.

The subsurface water is cold (10°C) and rich in phosphates and nitrates, nutrients which generally limit the growth of phytoplankton. Upwelling thus acts as a "conveyor belt", constantly replenishing nutrients to the coastal waters during periods of upwelling. The combination of abundant nutrients and adequate sunlight allows prolific phytoplanton growth (up to several million cells per liter during blooms) in the upper 50 meters of water.

W. E. Allen of Scripps Institute of Oceanography, studied and reported on the phytoplankton of southern California from 1921 to 1946. Among his conclusions (summarized by Riznyk, 1974) are the following. Maximum numbers of phytoplankton were found between 10 and 20 meters in shallow water, and 20 to 30 meters in deeper waters. In 20 years of daily collecting, only 100 species representing 41 genera were identified. Of these only 17 species were dominant; the genus *Chaetoceros* has the greatest total abundance. There is considerable variability in the annual biomass. Annual production tends to be greatest in the spring.

The Allan Hancock Foundation (1965) also conducted phytoplanton studies on the southern California shelf. Their results indicated that of all individual plankters counted, 54% were diatoms and 41% were dinoflagellates. Very large "blooms" were generally due to a single species. They found the diatom *Nitzschia* sp. to be the most widely occurring species. The most abundant dinoflagellate was *Prorocentrum micans*. Seasonal variation for diatoms indicated higher concentrations in summer than winter. Dinoflagellate concentrations showed less dependence on the season.

Similar studies off Oregon and Washington indicate that diatoms are the most abundant phytoplankters off the Pacific northwest coast, with dinoflagellates being the second most abundant (Anderson, 1972).

Hobson (1966) recognized species assemblages that were representative of inshore, transition, and offshore areas. According to an unpublished paper by Koga (cited by Anderson, 1972), the offshore community in winter was dominated by a diatom community (*Chaetoceros convolutus*, *Dactyliosolen mediterraneus*, *Thalassionema nitzschioides*) that also contained large numbers of dinoflagellates and coccolithophorids. During the spring the dominant diatom community changed composition, flagellates were not so common, and coccolithophorids were not observed.

The transition community contained a much less diverse flora than the offshore or inshore communities (about one-third the species). In winter only 8 species of diatoms were present. During spring 14 species of diatoms were present, but numbers were small.

The inshore community in winter in low-salinity water was dominated by the diatoms *Asterionella formosa*, *Melosira islandica* and *Thalassionema nitzschioides*. During spring the rich diatom flora was more diverse and dinoflagellates and other flagellates were common.

Red tides, or "blooms" of dinoflagellates resulting in high concentrations of several million cells/liter, are important in upwelling areas along the Pacific coast. They usually seem to occur when nutrients are low in the surface waters and a shallow thermocline develops. When these large concentrations of cells decay they produce noxious orders and use up the oxygen in the surface layers causing fish kills. Some dinoflagellates emit toxins that can kill marine organisms or concentrate in filter feeders consuming the dinoflagellates. An example is the mussel poisoning species Gonyaulax catenella which is restricted to the waters north of Point Conception, California on the Pacific Coast. Non-toxic dinoflagellates in Southern California have also caused red tides (Riznyk, 1974).

The production of phytoplankton can be measured as grams of carbon converted to organic matter (via photosynthesis) per unit area of sea surface (grams C/m^2). For comparative purposes, the following values are from Anderson (1972) and Curl (1970). Waters off southern California have an annual production of 200 to 400 grams C/m^2; the waters off the Oregon coast (out to 25 miles offshore) average 300 grams C/m^2; waters of the continental shelf beyond the influence of upwelling or river runoff average 125 grams C/m^2. These values compare with an oceanic average of 50 grams C/m^2.

(2) Zooplankton

Zooplankton biomass is closely related to the biomass of phytoplankton, as the latter serves as the primary food source for zooplankton. Therefore, zooplankton abundances follow phytoplankton abundances, although with a characteristic lag of several weeks, representing an exploitation and utilization phase of the plants by zooplankton.

An important segment of the zooplankton biomass is the meroplankton; those organisms which spend part of their lives as plankton, as opposed to holoplankton, which spend their entire lives as plankton. Examples of meroplankton are the larval stages of fish and other large marine organisms. The number and location of these plankters depends in part on the season and prevailing currents. Examples of meroplankton include larvae of crabs, spiny lobsters, sardines, mackerel, anchovy, halibut, and other important commercial fish species. The duration of the larval stage is variable but is generally less than several months.

Zooplankton of the North Pacific have been studied in terms of their relationship to oceanic water masses (major masses of water having measureably unique characteristics). It has been found that each water mass has one or more characteristic zooplankton species associated with it (Johnson and Brinton, 1963). These authors list four distinct faunal zones of the North Pacific: 1) subarctic, 2) transition, 3) Pacific central, and 4) equatorial. None of these zones has fixed geographical zones, but instead are associated with specific temperature-salinity relationships which are characteristic of the water masses. As a consequence, the arctic zone may extend to Baja California if the water mass characteristics are appropriate for arctic water. However, there is some resemblance between the water mass descriptions and the geographical regions.

The Pacific subarctic zone is the more northerly zone, characterized by the copepod species Calanus tonuus, C. cristatus, and the euphausiid Euphausia pacifica, among others. These species may at times be found far south in the California Current during the upwelling periods.

The transition zone is a diffuse boundary between subarctic and central populations, but apparently harbors endemic (particular to a specific locality) species; as well as populations of zooplankton common to the zones north and south. A chaetognath, Sagitta scrippsae is endemic to the zone (Johnson and Brinton, 1963), while Calanus pacifica occurs in the subarctic, transition, and central zones but is particularly abundant in the transition zone.

Characteristic zooplankton of the central faunal zone include Euphausia brevia and E. hemigibba. Central zone species are not particularly common off the U.S. Pacific coast, as this water mass is farther south and offshore. Under certain weather conditions, these species may "encroach" upon the Southern California coast. Equatorial species, such as E. eximia, may also be reported as occasional northern migrants during abnormal warming periods (Brinton, 1960).

Because of the efforts of the California Cooperative Oceanic Fisheries Investigations (CALCOFI) the zooplankton of California has been well documented. The seasonal medium zooplankton volumes of 1951-1960 (Smith, 1968) indicates that large populations of zooplankton (greater than 256cc/100m^3) occur at approximately the same period as upwelling in late spring and summer. As is predictable, copepods generally comprise the major portion of the plankton. From the nine years of pooled data McGinnis (1971) reported there was a general trend of a maximum concentration of zooplankton 80-120 miles offshore with diminishing concentrations toward the coast and further offshore towards the central water mass.

Day (1971) sampled zooplankton off Washington and found the biomass to be 90% euphausiids, 76% of which are *Euphausia pacifica* and 14% were *Thysanoessa spinifera*. Day also concluded that the zooplankton biomass was generally lowest near shore, reached a maximum at or near the seaward edge of the continental shelf, and decreased farther offshore.

In studies of the zooplankton off the coasts of Washington and Oregon during 1961 and 1962 for the upper 200 m, Peterson (1972) found that copepods made up the largest part of the zooplankton. Numbers and calculated wet weights of most copepods were highest near the surface and in summer. Often, the offshore areas had higher copepod populations in summer than inshore areas; in winter this situation was reversed. Evidence for daily vertical migration was slight or lacking for most of the common copepod species.

In addition to variations in the areal distribution of zooplankton, these animals undergo extensive daily vertical migrations as well. Euphausiids may ascend 500 to 700 meters during the evening, returning to the depths in the morning. Not all species of zooplankton undergo these migrations, while others show a number of variations in vertical migrations and depth preferences. The level of illumination is the most accepted "causal" mechanism associated with the vertical movements of zooplankton.

(3) Benthic Biota

Collectively, the benthic biota make up one of the most complex and least understood areas of marine biology. The complexity arises from the many diverse adaptions of these animals to their environment. These adaptions include burrowers, scavengers, suspension-feeders, predators, and parasites. In addition to their ecological importance in the sea, benthic organisms are of economic importance also. There are many valuable fisheries for benthic animals, such as shrimp, lobster, and halibut.

Bottom organisms along the Pacific coast are primarily distributed in area and density according to water temperature and type of substrate (sea bottom). Other factors influencing the benthos are water depth, distance from shore, currents, and food availability and water quality. Epifaunal communities reach their maximum development in the intertidal zone, while the infauna dominates the sea floor beyond the subtidal zone (Odum, 1971).

The primary source of food of shallow water benthic organisms includes living plants and animals, whereas deep-water benthic animals depend on the continual rain of dead organisms and detritus from above. This material is ingested by the primary consumers such as worms and molluscs. Other benthic organisms feed on organic material they encounter while burrowing in the sediments. The benthic community is therefore related to the surface water productivity. Surface waters of the U.S. Pacific coast are highly productive because of the upwelling process, discussed in a previous chapter. Correspondingly, a rich benthic community exists in this area.

The benthos of southern California has been relatively well studied by the Allan Hancock Foundation (1965). This is particularly true of the nearshore area originally termed the mainland shelf (Emery, 1960) which extends from shore to a depth of approximately 300 feet (100 meters). The Allan Hancock Foundation estimated the average standing crop biomass of the benthic macrofauna to be 356 grams/sq. meter. Emery (1960) reported a range in the standing crop of the mainland shelf to be 40-4,000 grams per sq. meter.

The major animal group found on the mainland shelf were the polychaetes. This class of annelid worms was the most widely distributed group, outranking any other group in species, numbers, and total weight. Nearly half of all specimens counted were polychaetes. Crustaceans, especially phoxocephalid amphipods, accounted for about 25% of all specimens but, because of their small size, seldom comprised more than 5% of the biomass. The small red brittle star Amphioda urtica (Echinoderm, Ophuiroida) was the most abundant single species (being found in 85% of all samples at depths greater than 30 feet) averaging 400 individuals per square meter. Bivalve mollusks were usually so small that they contributed only a small amount to the biomass, even though their shells were included in their weight. The echiuroid worm Listriolobus pelodes was not widespread, but heavily concentrated in the fine sediment near Santa Barbara. The brachiopod Glottidia albida was found in 60% of the samples. The above groups accounted for over 90% of the benthic biomass, and the majority of the 1,200 species that were collected.

The benthic studies of the other areas off southern California are summarized by the Southern California Coastal Water Research Project (1973). The numerous basins and troughs off the southern California coastline are a unique feature of the area. Because of their depth and their depression below the surrounding sea floor, they serve as sinks for organic detritus settling from overlying waters, and the dissolved oxygen in at least three of the basins is extremely low, from less than 0.1 to 0.4 mg/l. The fauna found in the basins was far less rich and diverse than that of the mainland shelf, and consisted primarily of polychaetes that could evidently tolerate the low oxygen conditions. The dominant species of the different basins differed remarkedly.

The submarine canyons contain a unique and varied fauna. Hartman's (1963) study showed that 30 to 60 percent of the species found in one canyon were not found in adjacent canyons, indicating some degree of isolation. Canyon habitats are subject to considerable fluctuations in environmental conditions because they serve as natural channels for shoreward movements of upwelling waters and organisms and for downward transport of runoff, sands and debris. These processes result in widely (and often suddenly) varying conditions, to which the indigenous fauna must adjust. In general, the variety and numbers of animals in canyons decrease with depth, as on the shelf and in basins. In all of the canyons, polychaetes represented the largest population of the total number of species; crustaceans and molluscs were present in significantly fewer and about equal numbers. Estimates of biomass in the canyons showed that the canyons are intermediate in standing crop between the basins and the shelf, with an average biomass of about 175 g/sq m.

The composition of benthic fauna of the central Oregon continental shelf changes with increasing depth and distance from shore (Carey, 1972). The epifauna changes from a sparse molluscan assemblage to one dominated by numerous echinoderms and arthropods. The infauna demonstrate a seaward variation in species composition; arthropods are dominant close to shore; and polychaetes are dominant offshore. Abundance increases seaward; the largest numbers and greatest biomass of both epifauna and infauna were found at the outer edge of the continental shelf.

Pereyra and Alton (1972) concluded that the distribution of organic carbon in the sediments off the northern Oregon coast appeared to be the environmental factor most responsible for the observed distribution of the benthic epifauna.

Lie (1969) and Lie and Kisker (1970) reported three communities which were distributed according to sediment type, depth, and distance from the Washington shore. The standing crop at the shallow water stations having fine sand substrates was dominated by crustaceans and small lamellibranchs (clams), whereas the deeper stations with silt-clay substrate were dominated by polychaetes and echinoderms.

According to Lie and Kisker (1970):

> The deepwater mud-bottom community identified previously as one of the three benthic communities off the coast of Washington was found at mean depths of 154.5 m in sediments with a mean mud percentage of 50.09%. The most abundant species were polychaetes, lamellibranchs, and an amphipod. The mean standing crop (ash-free dry weight) was 3.058 g/m^2, with echinoderms and polychaetes as the major contributors to the standing crop.
>
> The intermediate depth sand-bottom community was found at stations with a mean depth of 95.8 m in sediments with a mean sand percentage of 67.81%. The most abundant species were polychaetes and lamellibranchs. The mean standing crop was 2.533 g/m^2, with the lamellibranch *Macoma elimata* as the major contributor to the standing crop.
>
> There was a distinctly lower species diversity in the shallow water sand-bottom community than in the two communities in deeper waters.

(4) Active Swimmers - Nekton

The Pacific continental shelf nekton is strongly associated with the California Current and the coastal upwelling of nutrient rich waters. Presently the most numerous epipelagic fish of the California Current throughout California is the northern anchovy, although the Pacific herring is abundant in the Pacific Northwest. Anchovies are abundant off the Washington and Oregon coasts, particularly during the winter (Glude, 1971).

Some crustaceans such as the ocean shrimp Pandalus jordani spend much of their time as members of the pelagic community, but the pelagic red crabs (family Galatheidae) are probably the most important crustaceans in the pelagic community.

The midwater fauna off southern California is especially complex because it contains species from three converging water masses (Pacific Subarctic, North Pacific Central, Pacific Equatorial) as well as species endemic to the California Current system (Lavenberg and Eberling, 1967). Lavenberg and Eberling recognized specific groups of species associated with each of these water masses.

According to Miller and Lea (1972), there are 554 species of coastal marine fishes known to occur in California. This count includes only part of the midwater fauna, so the actual number of species is larger, The number of species decreases in a south to north direction, continuing off Oregon and Washington.

Considering the continental shelf demersal species (those fish associated with the bottom) SCCWRP (1973) reported 121 species off southern California to a depth of about 300 meters. Alton (1972), sampling in an area having fish typical of both Oregon and Washington, reported 92 species of demersal fishes from a depth interval of 91 to 2,121 meters.

Marine Mammals

The reported marine mammal fauna of the Pacific coast area and offshore islands consists of cetaceans, pinnipeds and one carnivore. According to Walker (1962) there are 30 species of North American whales and dolphins in the Pacific Ocean. Seven of these species are threatened with extinction, according to the Fish and Wildlife Service (see section III.1.b.6.).

Cetaceans are represented by the Mysticeti (baleen whales) and Odontoceti (toothed whales), the latter being by far the most abundant. The most common mysticeti is the California gray whale which migrate annually from their feeding areas in the Bering Sea to their breeding grounds in Scammon's Lagoon, Baja California, Mexico.

Six species of the Order Pinnipedia have been reported from the California, Oregon and Washington area. The California sea lion is the most abundant, followed by the Northern Elephant Seal, Stellar

Sea Lion, Harbor Seal, Northern Fur Seal, and Guadalupe Fur Seal. The single carnivore represented is the California sea otter which ranges primarily between Monterey Bay and Point Conception, California.

South of Point Conception, California, mainland breeding areas for pinnipeds are no longer utilized because of human habitation. Breeding areas are confined primarily to the offshore islands, particularly San Miguel and San Nicolas Islands (Carlisle and Aplin, 1970).

North of Point Conception pinnipeds still breed on certain mainland areas. Farther north, the California sea lion is replaced by the Stellar sea lion, while the Northern fur seal becomes the dominant species. Several smaller offshore rocks or islands, including the Farallon Islands, are also important breeding areas in the northern part of the Pacific coast.

(5) Birds

The Pacific coast of the United States between the Mexican and Canadian borders is typified by a large and varied composition of marine-associated bird life. As one proceeds north from Southern California the type of habitat available for marine birds increases. Offshore rocks, inlets, islands, and extensive areas of undeveloped and often inaccessable coastline increase, providing ideal habitat and breeding sites for birds. Oceanographic conditions along the Pacific coast from Point Conception to Washington produce extensive areas of nutrient-rich upwelling. This factor provides ocean waters rich in marine life and conducive to supporting large migrant and endemic populations of sea birds.

In Southern California the predominant available habitats are sandy beaches and coastal wetlands which receive heavy human population pressures. This environment is a less desirable habitat than the more desolate coastlines to the north and south. The Santa Barbara Channel Islands represent a unique area which supports very large populations of marine birds.

In addition to nesting seabirds, the southern California coastal zone and offshore areas are utilized during different periods of the year by a large host of resident and migratory waterfowl, shorebirds, and terrestrial birds.

Reynolds and Osborne (1971) listed in order of importance the following breeding seabirds for California: Cassin's auklet, common murre, western gull, Brandt's cormorant, Leach's petrel, ashy petrel, pelagic cormorant, pigeon guillemot, fork tailed petrel, rhinoceros auklet, double crested cormorant, tufted puffin, and black oyster catcher. The largest population of seabird breeding pairs in the State occurs in the two northernmost counties of Humboldt and Del Norte. Castle

Island in Del Norte County is second only to the Farallon Islands off San Francisco for total number of seabird breeding pairs in California (Osborne, 1971).

Essentially the same species composition of colonial breeding sea birds are in the States of Oregon and Washington. The U.S. Fish and Wildlife Service (April, 1972) cited colonial seabirds as being the most abundant birds present on the Oregon Islands National Wildlife Refuge (see section on refuges). These represent 18 colonial species with over half of them breeding along the Oregon coast. The most common in order of abundance are: Leach's petrel, common murre, fork tailed petrel, western gull, Brandt's cormorant, pelagic cormorant, glaucous-winged gull, tufted puffin, and pigeon guillemot. For the Washington Islands National Wildlife Refuge, the U.S. Fish and Wildlife Service (June 1973) cited 14 different species of colonial breeding seabirds. In order of abundance they are: Leach's petrel, rhinocerous auklet, tufted puffin, fork tailed petrel, common murre, glaucous-winged gull, western gull, Brandt's cormorant, pelagic cormorant, Cassin's auklet, black oyster catcher, pigeon guillemot, double crested cormorant, and the hybrid glaucous-winged western gull. Over 150,000 breeding pairs are listed as populating this area.

The largest single species of bird represented in the migrants are the shearwaters which pass along the Pacific coast on their seasonal migration from Alaskan waters south to their breeding grounds in the Southern Hemisphere.

The States of Washington, Oregon and California make up the Pacific Flyway for water fowl in the United States. Ducks and geese using the Pacific Flyway breed during the summer months in the prairie provinces of Alberta and Saskatchewan, Alaska, the Yukon, parts of the Northwest Territories, British Columbia, Siberia and in the flyway States (California Dept. of Fish and Game, 1970. Those birds originating in Siberia, Alaska, the Yukon and the Northwest Territories of Canada utilize the coastal wetlands of Oregon and Washington and, in particular, the coastal wildlife refuges such as Willapa National Wildlife Refuge on the central Washington coast. Portions of these migrants continue down the length of the Pacific coast to winter on the coastal wetlands of southern California.

In summary, the coastal zones and offshore areas of California, Oregon, and Washington host a large population of marine associated birds and waterfowl. This is due to an abundant marine food supply, extensive areas of inaccessible coastline and offshore rocks, and low human population pressures. The majority of the offshore seabird breeding and roosting sites in Oregon and Washington are part of the Federal refuge system.

(6) Unique Environments

The whole Pacific coast, with its water temperature, current, upwelling, rocky shores, etc., is unique, being substantially different from the other coastal areas of the United States. However, within the Pacific coast region, there are certain features which are extremely important.

1. Kelp Beds: One of the most important habitats to the Pacific coastal areas are the kelp beds. Extending from just past the surf zone to depths of 100 feet, these plants form a habitat for numerous species and individuals of fish and invertebrates. Standing crop estimates of resident fishes in kelp beds are close to values for lakes and coral reefs. Incorporating invertebrate biomass into this figure would increase the standing crop value many times (Quast, 1969). South of Point Reyes, California, the giant kelp (Macrocystis) is the most numerous genus while north of this point bull kelp (Nereocystis) becomes the dominant genus.

2. Offshore Islands and Rocks: The eight offshore islands of southern California are essentially the only remaining relatively-unaltered coastal and associated upland habitats remaining in this region. These islands and the numerous offshore rocks along the remaining Pacific coast serve as important and sometimes the only remaining breeding and hauling out regions for seals and sea lions, and are extremely important nesting areas for sea birds. For example,

Anacapa Island is the only active breeding ground off the west coast of the U.S. for the endangered brown pelican.

3. Subtidal Rock Outcrops on Banks: Scattered along the Pacific continental shelf, usually near its outer edge, are shallow rocky banks rich with attached organisms and associated fish. Tanner and Cortez Banks off southern California are typical of this type of environment. Off San Francisco are the Farallon Island shoals and Cordell Bank; off Oregon are Hecta and Stonewall Banks.

4. Submarine Canyons: Submarine canyons such as Scripps, Newport, and Monterey, are also scattered along the continental shelf of the Pacific coast. These may be considered unique environments, because of the proximity of deep water and steep rocky submarine cliffs, literally a few hundred yards from the beach.

5. Bays and Estuaries: In southern California there are only a few estuaries which, like Mugu Lagoon, are unaltered. These are unique for the area. Several other estuaries (San Francisco Bay, Willapa Bay), are important marine bird migrations because of their size, or to fisheries and offshore hydrology (Columbia River Estuary).

e. Natural Phenomena Unique to Area with Potential to Cause or Contribute to Environmental Impacts of Proposed Action

Natural phenomena with the potential to cause or contribute to environmental impacts are primarily geologic (such as earthquakes, natural oil seeps, landslides), meteorological (winds, topical hurricanes), and oceanographic (waves, tsunamis). These phenomena and their effects have been discussed in sections II.A.3., II.A.3.b., and II.A.3.c., respectively. The sections include natural phenomena associated with the nearshore environment, in addition to the offshore environment.

4. Alaska Region

a. Geology

General

Alaska is situated at the northern end of the Americal Cordillera--the continuous mountain system which extends the entire length of western North and South America. As such, Alaska is similar, both structurally and physiographically, to other parts of the mountain complex. Table 10 relates analogous features of the Alaskan and conterminous U.S. cordilleran sections. Dynamic earth processes continue to alter both regions. The Aleutian Island Chain is one of the most seismically active (earthquake-prone areas of the world, while noticeable movement along active fault zones in central and southern California occur continually.

TABLE 10 ANALOGOUS NORTH AMERICAN CORDILLERAN FEATURES

Alaska	Western U.S.
Arctic Coastal Plain	Interior Plains
North Slope	High Plains of Colo., Wyo., Mont.
Brooks Range	Rocky Mountains System
Yukon-Tanana Valley	Columbia Plateau/Basin and Range Province
Aleutian Island Chain/ Alaska Range	Cascade-Sierra System
Coastal Trough	Puget Sound-Willamette-Great Valley (Cal.) Lowland
Pacific Border Ranges (Chugach, St. Elias, Kenai Mts.)	Olympic Mts.-Coast Range of Wash., Ore., Cal.

Geologic Hazards in Alaska

Geologic hazards that may occur in present and future production areas of the Alaskan OCS are likely to be significant. The southern Alaska coast is characterized by frequent earthquakes, fault offset and local volcanism. Further north as seismic hazards diminish, problems related to the distribution and nature of permafrost demand more attention.

Permafrost

Permafrost refers to the permanently frozen zone of soil, subsoil, or other earth materials which underlies much of the higher-latitude regions of the world. Areal distribution of permafrost in Alaska varies considerably. Much of the northern and western sections of the State are underlain continuously, while southern areas are virtually free from its occurrence (Fig. 48). Permafrost distribution in the remaining parts of Alaska is quite variable, ranging from isolated patches to broad discontinuous areas.

Most of the current permafrost in Alaska formed several thousand years ago during periods of extreme cold. Relict thicknesses exceeding 100 feet are common, while a maximum thickness of 2000 feet has been reported in the Prudhoe Bay area (Howitt and Clegg, 1970).

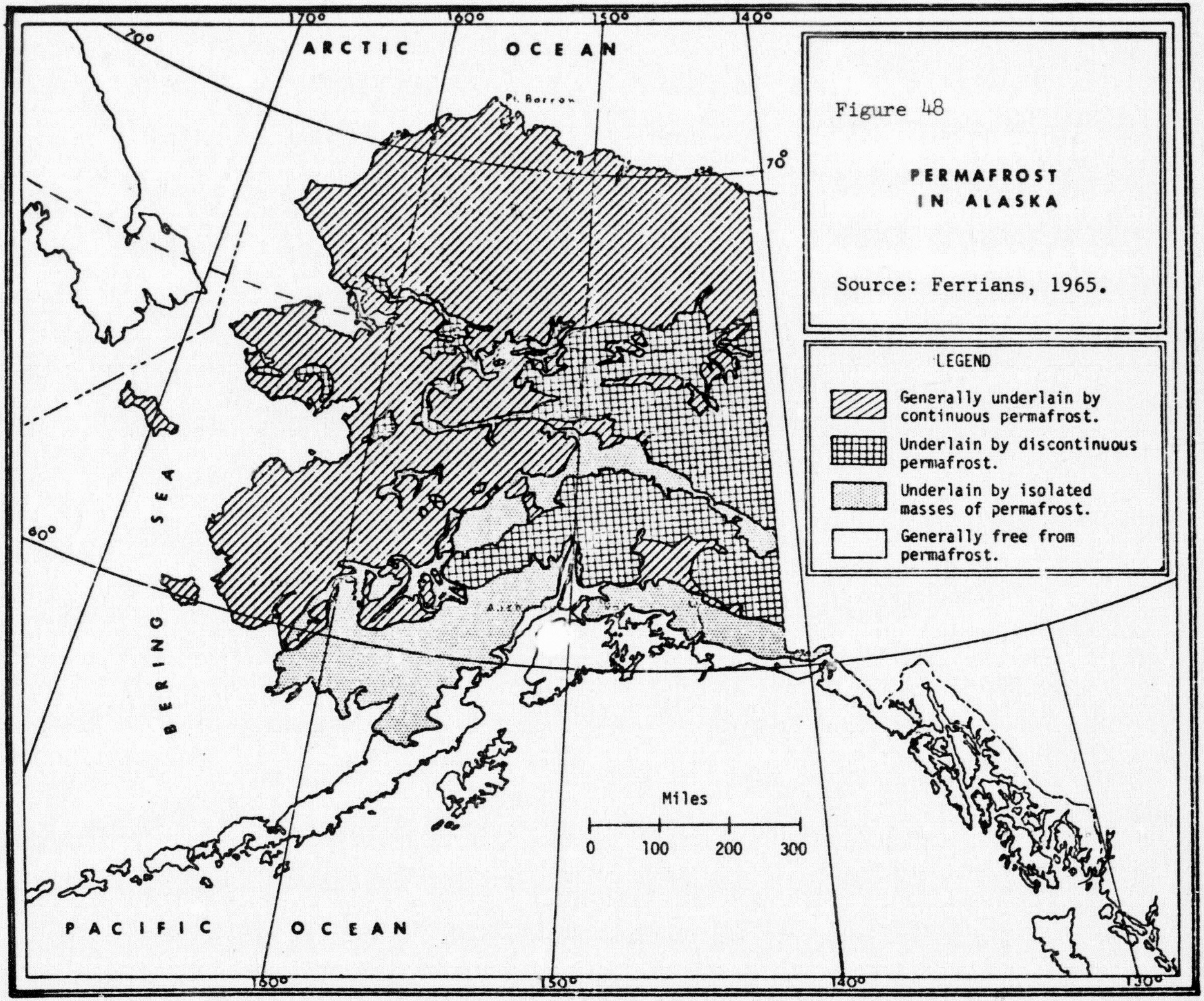


Figure 48

PERMAFROST IN ALASKA

Source: Ferrians, 1965.

LEGEND
▨ Generally underlain by continuous permafrost.
▦ Underlain by discontinuous permafrost.
░ Underlain by isolated masses of permafrost.
☐ Generally free from permafrost.
ARCTIC OCEAN
Pt. Barrow
170°
160°
150°
140°
70°
70°
60°
BERING SEA
PACIFIC OCEAN
Miles
0
100
200
300
160°
150°
140°
130°

All permafrost regions in Alaska are subject to seasonal surface thawing. This "active zone" of summer melting generally deepens southwards ranging from 1/2 foot to greater than 5 feet, although physical conditions can induce considerable local variation. Surface melting of the permafrost layer can increase the potential for solifluction--the downslope movement of water-saturated soils. In addition, successive freeze-thaw episodes characterized by incomplete refreezing within the active zone may isolate a water-laden thaw layer below the frozen surface. The rigid surface is then prone to frost-heaving, cracking and displacement. Accelerated coastal erosion can occur in some areas due to wave action on thawed permafrost. Artificial influences (e.g. structures, excavation, pipelines) which alter the surface thermal regime or drainage pattern can aggrevate these permafrost phenomenon and increase soil instability.

Knowledge of the extent and thickness of permafrost beneath the northern seas is largely speculative. The relatively few drill holes attempted in these areas revealed the top of the permafrost occurring from a few meters to over 100 meters below the sea bottom. However, these drilling operations have rarely penetrated the entire section.

Recent surveys of the Beaufort Sea have revealed the presence of "pingos", or relatively large mounds on the sea floor.raised by frost action above the permafrost. These features, which occasionally come within 15 meters of the water surface, pose a potential hazard to deep-draft shipping, if undetected.

Earthquakes

The Gulf of Alaska-Aleutian Island Arc area is prone to frequent and occasionally severe earthquakes (Fig.49). During the last 70 years, eight seismic events had recorded magnitudes that equalled or exceeded Richter 8 in that region. The most recent, the 1964 Prince William Sound (Good Friday) earthquake was recorded at Rickter 8.3-8.6. Exhaustive studies have been made on the effects of this quake. Among the more complete works are those by the National Academy of Sciences (1968-73) and the U.S. Geological Survey (1966-70).

Historically, the most severe earthquake damage has involved either structural failure caused by dynamic shaking or foundation failure resulting from ground rupture or loss of soil stability. Additional related phenomena include mass wasting (rock slides, mud slides, avalanches), differential settlement and seismic sea waves and seiches. Although severe damage during an earthquake is usually restricted within a 100 to 200 mile radius of the original epicenter, high intensity aftershocks can be initiated several hundred miles along the active fault system. Figure 50 delineates zones of potential damage from seismic events within the state.

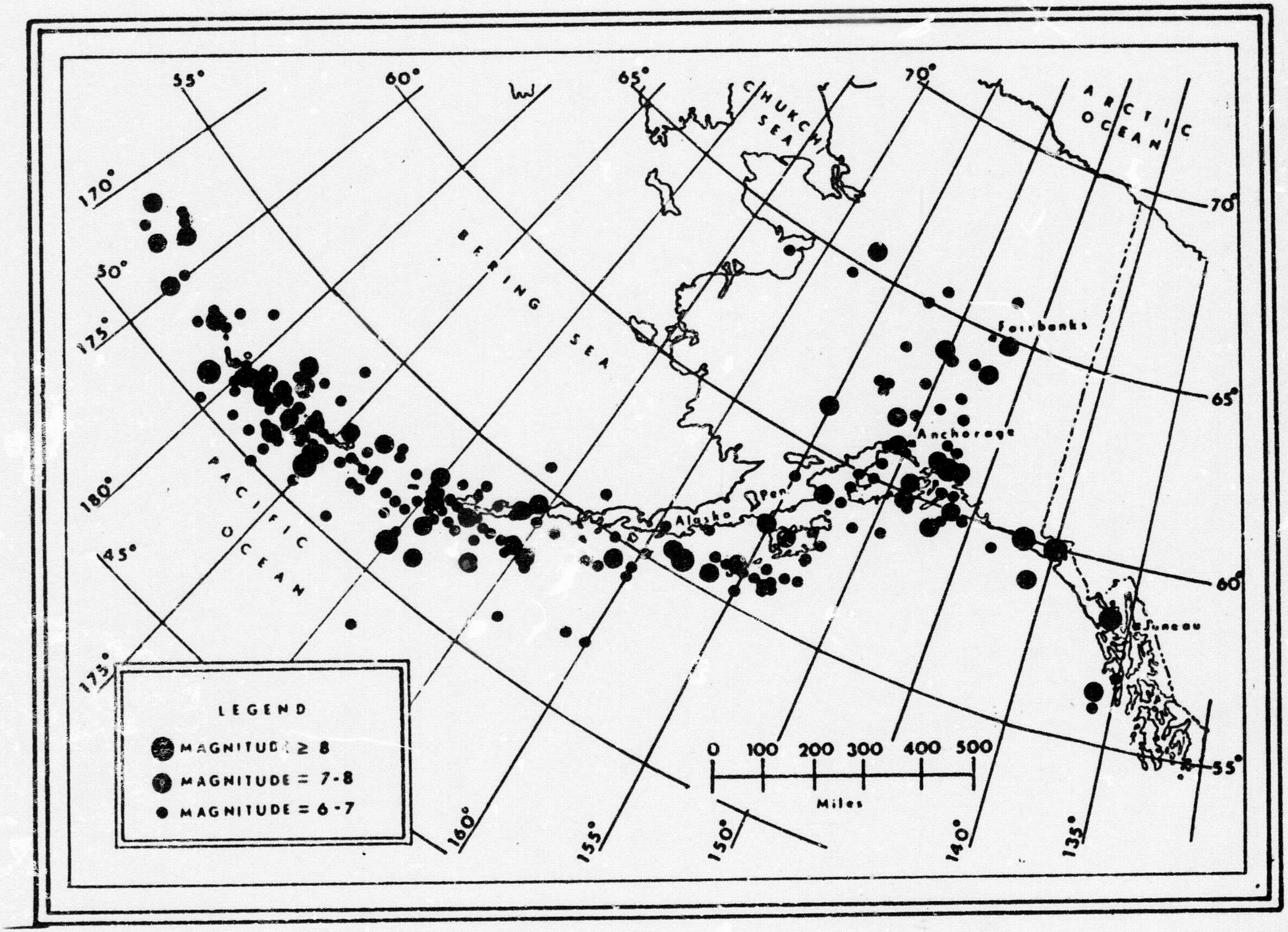
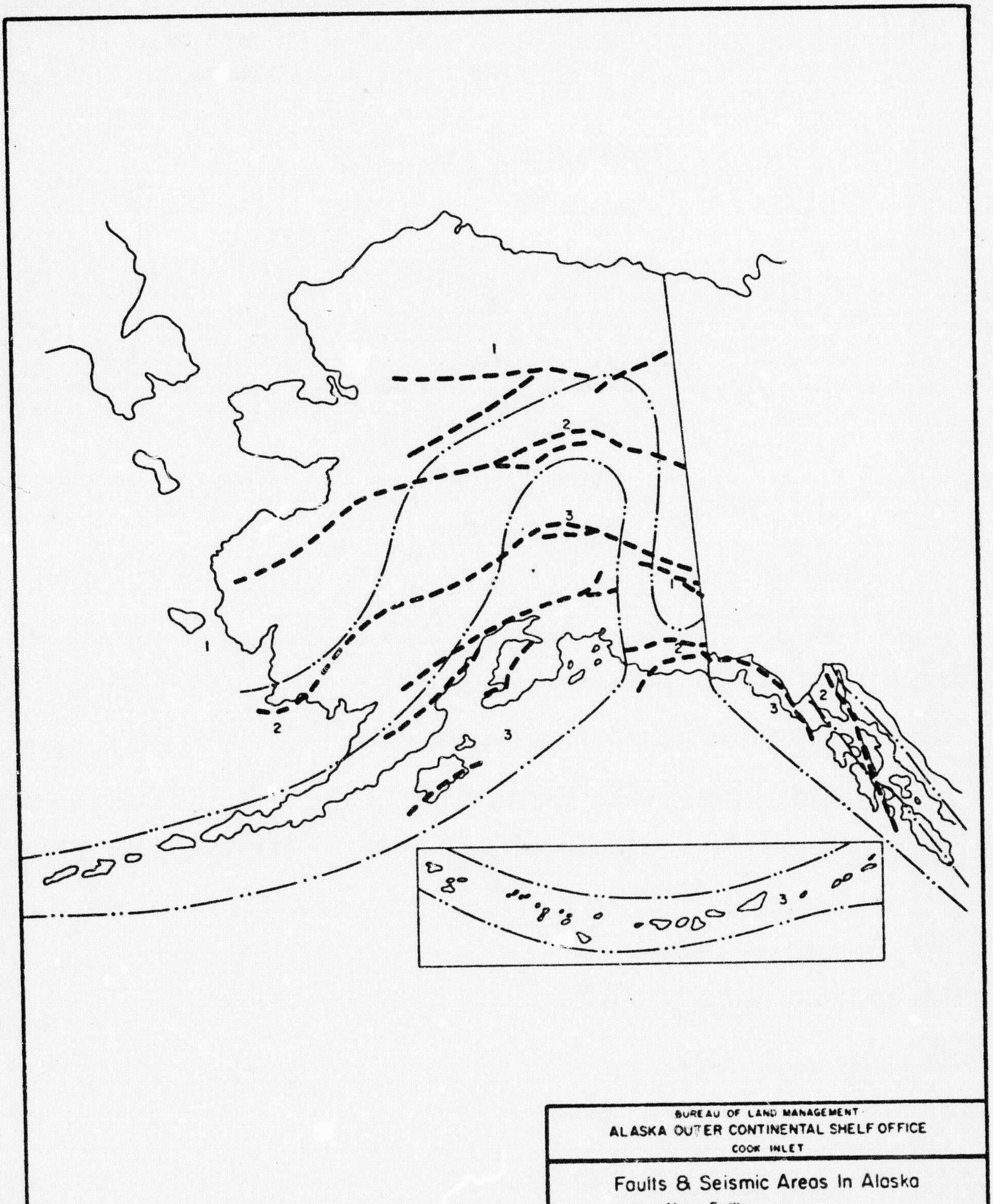

ARCTIC OCEAN
CHUKCHI SEA
BERING SEA
PACIFIC OCEAN
Fairbanks
Anchorage
Juneau
Alaska Pen.
55°
60°
65°
70°
70°
65°
60°
55°
45°
50°
170°
175°
180°
175°
160°
155°
150°
140°
135°
0 100 200 300 400 500
Miles
LEGEND
MAGNITUDE ≥ 8
MAGNITUDE = 7-8
MAGNITUDE = 6-7

Figure 49 EARTHQUAKES IN ALASKA. MAGNITUDE ≥ 6, 1899–1964 FROM: U.S. COAST AND GEODETIC SURVEY, 1966


1
2
3
1
2
3
1
2
3
2
3
BUREAU OF LAND MANAGEMENT
ALASKA OUTER CONTINENTAL SHELF OFFICE
COOK INLET
Faults & Seismic Areas In Alaska
Major Faults
Seismic Zones
1-Minor structural damage(3.0-4.5)
2-Moderate structural damage(4.5-6.0)
3-Major structural damage(6.0-8.8)

Source: Compiled in 1971 by the Federal Field Committee for Development Planning in Alaska from authoritative sources

Figure 50. Faults and Seismic Areas in Alaska.

Faults

Swift et al. (1974) list the major fault systems in Alaska, from north to south, as:

1. Kaltag fault, extending from the southern side of Norton Sound to Tanana.
2. Tintina fault, bordering the south side of the Kandik Basin.
3. Denali fault system, extending in a hugh arc parallel to the south coast of Alaska from Bristol Bay past the Alaska Range.
4. Bruin Bay fault, bordering Lower Cook Inlet on the west and extending southwestward down the Alaskan Peninsula.
5. Castle Mountain fault, north of Anchorage, bordering the north side of Cook Inlet.
6. Fairweather fault, a north-northwestward trending fault that passes southwest of Juneau and Skagway.
7. The Chugach and St. Elias system that extends in an arc from Cordova into the Pacific Ocean southwest of Yakutat.

The potential for significant activity along these fault systems increases in a southerly direction, towards the seismally-active areas of southern Alaska.

Volcanic Activity

The intense seismicity of the south Alaska coast is accompanied by active volcanism along much of the Alaskan Peninsula-Aleutian Island arc. The Aleutian Islands alone contain 76 major volcanos, about half of which have been active historically (Coats, 1950). Active volcanos are absent east of Cook Inlet and also along the western 600 miles of the Aleutian Island arc where the oceanic trench and related seismic events are less pronounced (Burk, 1965).

Volcanic eruptions in the Aleutian Island arc system tend to be more violent than those occurring within ocean basin areas, reflecting chemical differences in the materials involved. Physical phenomena commonly associated with these volcanic eruptions include: explosive ejections of fine (ash) to coarse debris, lava flows, release of toxic and corrosive gases, volcanic earthquakes, and potential mud flows, corrosive rains, flash floods and abnormal sea waves. Hazardous effects of these events are normally limited to local onshore areas; their importance would diminish with increasing distance from shore.

(1) Gulf of Alaska

(a) General

The Alaskan Pacific-margin Tertiary basin is a 900 mile-long structural feature that roughly parallels the southern Alaska coast between Cross Sound and Chirkof Island. The basin covers an area of approximately 40,000 square miles (103,600 sq. km), mostly offshore, and is underlain by a thick section of

Tertiary continental and marine strata varying in age from Paleocene through Pliocene. The basin sequence broadly includes a lower unit of well-indurated intensely-deformed early Tertiary rocks overlain by a less-altered section of mid to late Tertiary strata.

The Tertiary basin is subdivided into two petroleum provinces, the Gulf of Alaska Tertiary province on the east and the Kodiak Tertiary province on the west. Although similar stratigraphically, these two areas display significantly different structural trends. The structural regime of the Gulf of Alaska province is characterized by east-trending features and fault types that are similar to those found onshore, while the Kodiak province displays the regional N45°E structural trend and nearshore zone of high-angle faulting of the Aleutian structural system (Von Heune, 1972). Figure 51 presents a generalized structural cross-section through the Kodiak Tertiary province.

(b) Hydrocarbon Potential

Since most of the known seeps and other indications of hydrocarbon are thought to have been formed in the mid to late Tertiary sedimentary sequence, Plafker (1971) suggests that these strata hold the best petroleum potential.

Tertiary strata within the Pacific-margin basin are bordered on the north and partially underlain by highly altered Cretaceous

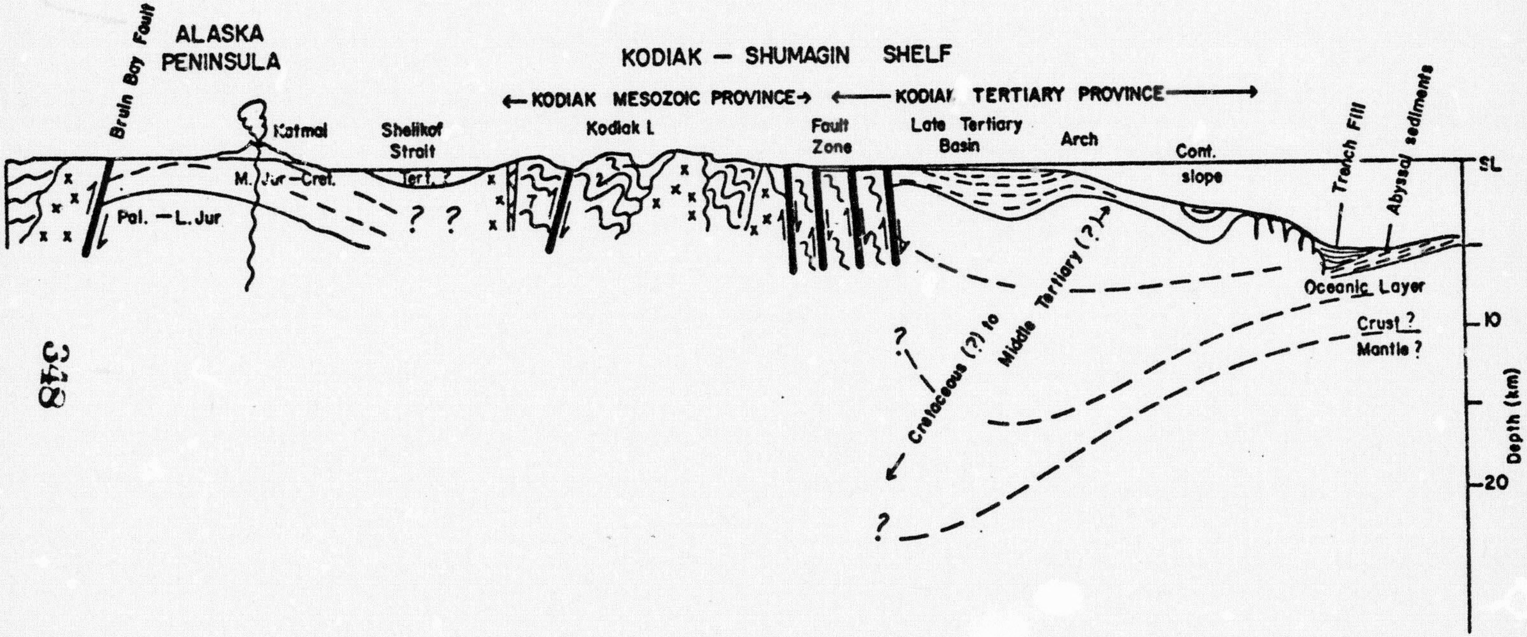

Bruin Bay Fault
ALASKA PENINSULA
KODIAK — SHUMAGIN SHELF
← KODIAK MESOZOIC PROVINCE →
← KODIAK TERTIARY PROVINCE →
Katmai
Shelikof Strait
Kodiak I.
Fault Zone
Late Tertiary Basin
Arch
Cont. slope
Trench Fill
Abyssal sediments
SL
M. Jur — Cret.
Tert. ?
Pal. — L. Jur
? ?
Middle Tertiary (?)
Cretaceous (?) to
?
?
Oceanic Layer
Crust ?
Mantle ?
10
20
Depth (km)

Figure 51. Generalized cross-section, Western Gulf of Alaska (from A.E.I. and D.C., 1974; after Von Heune, et al., 1971 and Von Heune, 1972).

and other pre-Tertiary rocks that are considered to have no petroleum potential, but which may form an effective basement for more promising strata above.

The narrow continental shelf off southeastern Alaska is thought to be underlain by mainly non-prospective pre-Tertiary strata. Unmetamorphosed pre-Tertiary rocks which underlie the Heceta Island and Keku Islands areas, however, could contain petroleum (Gates et al., 1968).

(c) Geologic Hazards

The Gulf of Alaska OCS area is characterized by a great variety of potential geologic hazards, both onshore and offshore. As previously mentioned, the Western Gulf is seismically active and prone to frequent fault displacements. Figure 52 , which shows regional effects of the 1964 Prince William Sound earthquake, is instructive in providing an estimate of the destructive influence of future high-magnitude earthquakes that may occur in the same area.

The extremely rugged northern Gulf coastline is extensively glaciated, with many of the ice flows extending to the shoreline.

(2) Lower Cook Inlet OCS

(a) General

Cook Inlet is an elongate, northwest-trending coastal embayment located in southcentral Alaska, just east of the

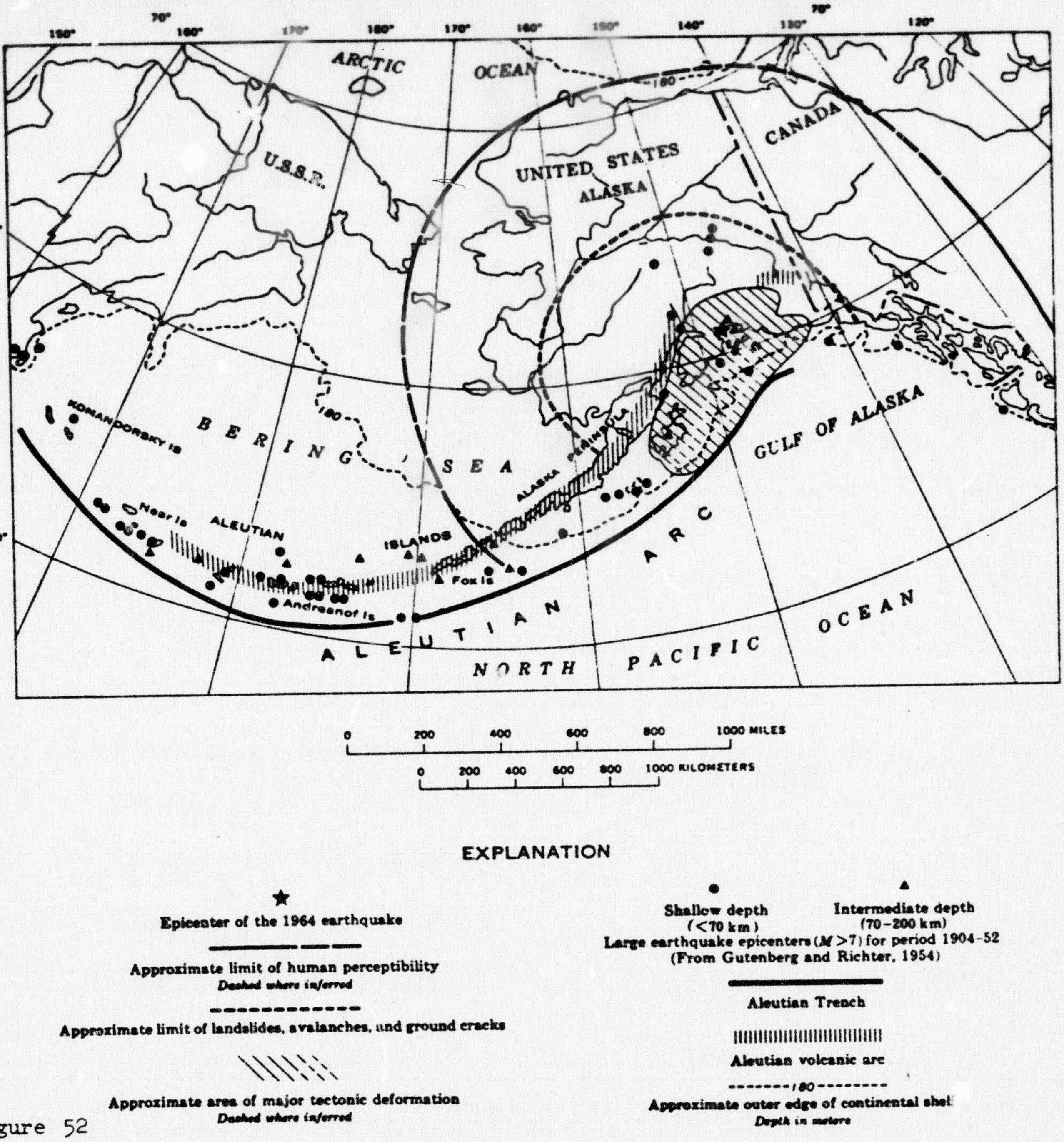

ARCTIC
OCEAN
U.S.S.R.
UNITED STATES
ALASKA
CANADA
BERING SEA
KOMANDORSKY IS
Near Is
ALEUTIAN ISLANDS
Andreanof Is
Fox Is
ALASKA PENINSULA
GULF OF ALASKA
ALEUTIAN ARC
NORTH PACIFIC OCEAN
180
190°
70°
160°
170°
180°
170°
160°
150°
140°
130°
70°
120°
60°
50°
0
200
400
600
800
1000 MILES
0
200
400
600
800
1000 KILOMETERS
EXPLANATION
Epicenter of the 1964 earthquake
Approximate limit of human perceptibility
Dashed where inferred
Approximate limit of landslides, avalanches, and ground cracks
Approximate area of major tectonic deformation
Dashed where inferred
Shallow depth
(<70 km)
Intermediate depth
(70-200 km)
Large earthquake epicenters (M>7) for period 1904-52
(From Gutenberg and Richter, 1954)
Aleutian Trench
Aleutian volcanic arc
180
Approximate outer edge of continental shelf
Depth in meters

Figure 52

Map of Alaska and adjacent areas showing the location of the 1964 earthquake, the area affected by the earthquake, epicenters of previous major earthquakes, belts of active volcanism, and the Aleutian Trench.
(from Plafker, 1969).

Alaskan Peninsula. The Inlet measures roughly 230 miles in length and 85 miles in width. Water depths average generally less than 90 meters but increase southward to over 180 meters at the mouth of the estuary.

Bottom sediments are fine grained silt and clay representing the heavy sediment influx from rivers and streams that drain the rugged, glaciated terrain surrounding the Inlet.

Cook Inlet is both a topographic and structural basin that contains about 60,000 feet of Mesozoic and Cenozoic sedimentary rock. The older Mesozoic strata which crop out around the edge of the basin are primarily of marine origin while the thick younger Tertiary sequence is largely non-marine.

The basin is bounded by faults that parallel the general northerly structural grain of the region. Structural ridges within the basin are similarly aligned; many of these anticlines are associated with long, parallel reverse faults. All of the oil and some of the gas discovered in Cook Inlet has been in structural traps occurring along these trends (Crick, 1971).

(b) Hydrocarbon Potential

Cook Inlet basin represents the southern part of the 15,000 square mile (38,850 sq. km) Cook Inlet petroleum subprovince; also included is the Susitna Basin to the north. About one-third of the Cook Inlet subprovince has been explored by drilling. The Lower Cook Inlet, covering an additional third of the total subprovince, is essentially unexplored. Available data indicate that the Lower Inlet has a thinner stratigraphic section with less structural potential than Upper Cook Inlet. Promising structures are present, however, and the erratic distribution of non-marine Tertiary strata within the sedimentary sequence suggests that stratigraphic traps may also exist, throughout the basin. Potential for gas discoveries in Lower Cook Inlet should be good.

(c) Geologic Hazards

Lower Cook Inlet lies within the seismically active zone of southern Alaska (Fig. 50) At least 12 major earthquakes of magnitude greater than Richter 6 have occurred in the local area since 1899.

Although the eastern half of Cook Inlet is located within the zone of major tectonic deformation associated with the 1964 Prince William Sound earthquake, existing oil and gas wells in the area were not appreciably disturbed (Eckel, 1966). Fissured ground, mud and landslides, intense vibration, and ground movements were widespread, however, and can be expected to pose potential hazards to future offshore oil and gas development, during periods of seismic activity.

Of the five volcanoes that occur in the vicinity of western Cook Inlet, three have erupted during the last 21 years. These eruptions have caused local damage from ash falls, sea waves and flooding. Augustine Island, an active volcano located in southwestern Cook Inlet, represents the most immediate volcanic hazard to future oil and gas operations within the Lower Inlet.

(3) Southern Aleutian Shelf OCS

(a) General

The Southern Aleutian Shelf forms a narrow arcuate zone that is sandwiched between the Aleutian Islands-Alaskan Peninsula on the north and the Aleutian Trench on the south. Width of the shelf varies from less than 50 miles (80 km) west of Unimak Island to about 150 miles (240 km) in the east, near Kodiak Island. The main shelf area is characterized by the presence of broad pleateau-like areas dissected by relict glacial drainage channels. Regional slope gradients are generally less than $0^{\circ}5'$. The shelf break is very distinct and occurs in water depths from 120-130 meters off Unimak Island to 150-160 meters off Kodiak Island.

Shelikof Strait, separating Kodiak Island from the Alaskan Peninsula, represents the best-defined of a series of broad, flat-bottomed submarine valleys that parallel or sub-parallel the mainland coast, and are thought to relate to the current tectonic regime of the area.

Beyond the continental shelf, a steep, rugged continental slope drops more than 5,000 meters to the Aleutian trench over a horizontal distance of 30 to 80 km. Von Huene (1972) characterized the slope topography as a relatively smooth upper section, a bench-like middle section and a steep, irregular lower section. The bench areas apparently signify large-scale slumping.

(b) Hydrocarbon Potential

Tertiary sedimentary rocks of the Kodiak Tertiary petroleum province extend westward beneath the South Aleutian Shelf OCS area to the vicinity of Chirikof Island. The petroleum potential of this province was discussed previously as part of the Pacific Margin Tertiary Basin (see section IIA4a(1)(b)) Although seismic data covering the western shelf is available, insufficient faunal and lithologic information exists to allow a meaningful evaluation of resource potential.

(c) Geologic Hazards

Much of the seismic activity associated with island arcs is confined to the zone which separates the active volcanic island chain from the oceanic trench. Since the Southern Aleutian Shelf occupies that area of the Aleutian Island Arc system, seismic risk is accordingly high. In addition, volcanic hazards, discussed previously, are evident in all but the westernmost part of the island chain.

(4) Bristol Bay OCS

(a) General

The Bristol Bay OCS area falls within the large Bristol Bay basin, a structural and sedimentary trough bounded by the Alaska Peninsula arch and the related Bruin Bay fault on the southeast, and by the Goodnews Arch and its seaward projection on the northwest. Exposures of highly-deformed, locally intruded Paleozoic and Mesozoic rocks delineate the northeastern margin of the basin while its southeastern extension terminates with the continental slope (Fig. 53).

The northeast region of the Bristol Bay basin contains from 2000 feet to 16,000 feet (610-4880 m) of non-marine and shallow water marine Tertiary rocks. The central province is distinguished stratigraphically by a thin eastern non-marine sequence that thickens southwestward to over 12,000 feet (3660 m) while assuming a more marine character.

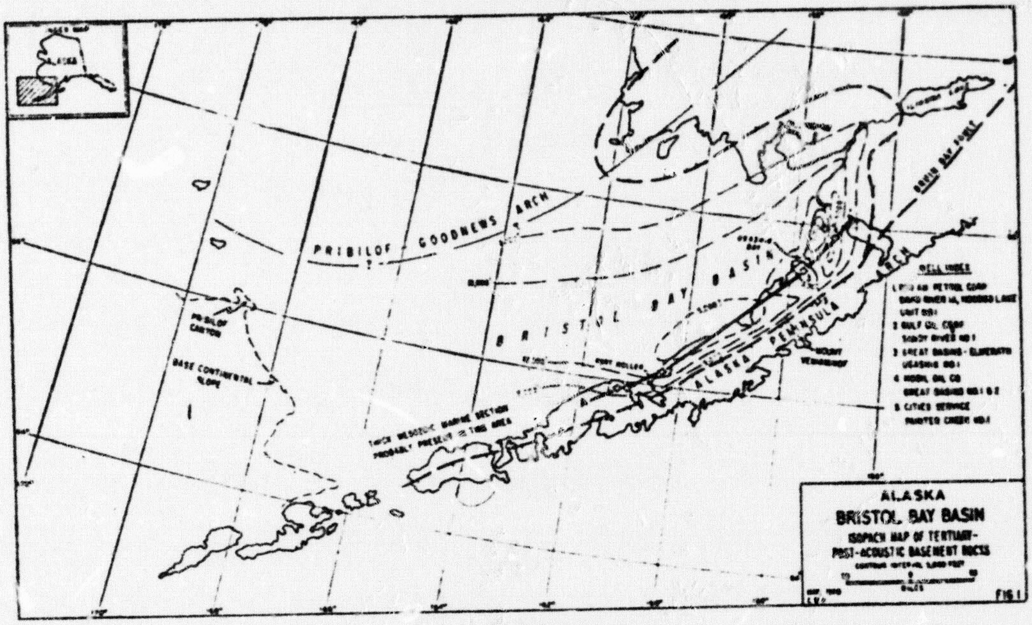

ALASKA
PRIBILOF - GOODNEWS ARCH
BRISTOL BAY BASIN
ALASKA PENINSULA
PRIBILOF CANYON
BASE CONTINENTAL SLOPE
THICK MESOZOIC MARINE SECTION PROBABLY PRESENT IN THIS AREA
PORT MOLLER
MOUNT VENIAMINOF
BRUIN BAY FAULT
WELL INDEX
ALASKA
BRISTOL BAY BASIN
ISOPACH MAP OF TERTIARY-POST-ACOUSTIC BASEMENT ROCKS
FIG 1

Fig. 53a

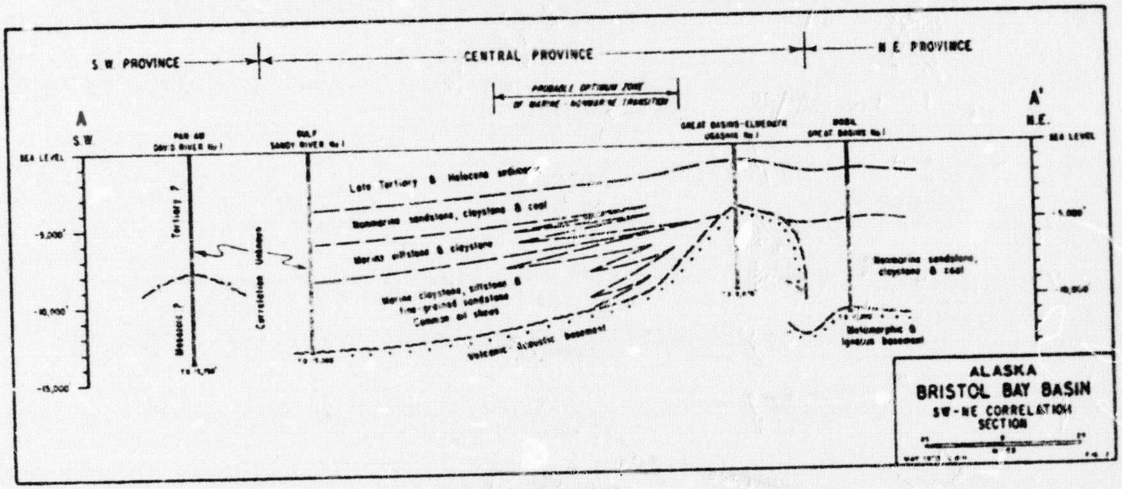

S.W. PROVINCE
CENTRAL PROVINCE
N.E. PROVINCE
PROBABLE OPTIMUM ZONE OF MARINE-NONMARINE TRANSITION
A
S.W.
A'
N.E.
SEA LEVEL
-5,000'
-10,000'
-15,000
PAN AM DAVID RIVER No 1
GULF SANDY RIVER No 1
GREAT BASINS-ELDERBERRY UGASHIK No 1
MOBIL GREAT BASINS No 1
Late Tertiary & Holocene sediments
Nonmarine sandstone, claystone & coal
Marine siltstone & claystone
Marine claystone, siltstone & fine grained sandstone Common oil shows
Volcanic acoustic basement
Nonmarine sandstone, claystone & coal
Metamorphic & igneous basement
Tertiary ?
Mesozoic ?
Correlation Unknown
ALASKA
BRISTOL BAY BASIN
SW-NE CORRELATION SECTION

Fig. 53b

Figure 53. Structural Aspects of the Bristol Bay Basin. (from Hatten, 1971).

Structural deformation in the sedimentary sequence of the Bristol Bay basin is most pronounced along the northwest flank of the Alaska Peninsula arch. Extensive faulting has also occurred in the volcanic basement of the central Bristol Bay basin, however these features do not appear to extend into the overlying beds. Mesozoic strata to the southwest have been faulted and broadly folded out to the edge of the continental slope, while the overlying Tertiary section is only mildly deformed (Scholl and Hopkins, 1969).

(b) Hydrocarbon Potential

Hatten (1971), summarizing a discussion of the petroleum potential of the Bristol Bay basin, concluded: "Large commercial quantities of hydrocarbons can be anticipated in structural and stratigraphic traps within a wide belt of transition between a marine Tertiary section in the southwest part of the basin and a non-marine Tertiary section in the northeast. Other accumulations may be found in the marine Mesozoic rocks of the southwest. . . ."

An estimated 1 to 2 million acres of the Bristol Bay OCS region have petroleum potential.

(c) Geologic Hazards (See also Sec. II.A.4.a Intro.)

Potential geologic hazards in the Bristol Bay region involve primarily seismicity and permafrost. The area is relatively close to the seismically-active Aleutian arc and falls mostly within seismic risk zone 2, signifying moderate potential structural damage (see Fig. 50). Sporadic volcanic activity along the southern coastal areas exerts a local influence. To the north, the onshore Denali fault system probably extends offshore, however this system has not shown appreciable activity in recent times (Swift, et al., 1974).

Isolated patches of permafrost occur at highly variable depths throughout the northern onshore regions of Bristol Bay (Ferrians, 1965). The nature and distribution of offshore permafrost, however is not currently known.

(5) Bering Sea OCS

(a) General

Nearly half of the total Bering Sea is underlain by a relatively smooth continental shelf which forms the southern portion of the expansive Bering-Chukchi Platform. The Bering Shelf segment is widest along the eastern and northern coasts, extending offshore over 400 miles in some places. It swings northwest near Unimak Island, then narrows considerably along the Kamchatka Peninsula to enclose the Aleutian (Bering Sea) Basin. Water depths over the Alaskan Bering Sea shelf average about 55 meters. The virtually flat shelf terminates abruptly seawards at about 160 meters water depth, giving way to one of the steepest known continental slopes. At average declivities that commonly exceed 20° (Dietz, et al., 1964), the irregular slope drops quickly from the shelf break to the 3800-3900 meter depths of the Bering Sea basin.

Several islands surface above the Bering Sea shelf. Many of these islands represent thick accumulations of volcanic flows and debris interspersed with some sedimentary strata.

Acoustic reflection records reveal a generally thin cover of Holocene sediments overlying the southeast Bering Sea shelf. While varying from 0 to 10 meters, sediment thickness averages 3 meters in this area (Moore, 1964). The unconsolidated Holocene sediment cover over the northeast Bering Sea shelf is similarly thin, but more variable in thickness. Fine sand is shown to be the predominant sediment type in the area in contrast to the generally finer-grained bottom constituents of the Chukchi Sea to the north.

Most of the Holocene sedimentation along the eastern Bering shelf has apparently occurred at the delta fronts of major coastal rivers, with relatively little redistribution of material across the shelf.

The Bering Sea OCS area contains several sedimentary and structural basins that have served as centers of Cenozoic deposition. The Norton Basin, covers an area of about 38,600 square miles (100,000 sq. km) extending from the shores of Norton Sound westward to Cape Chukotsky and between the Seward Peninsula on the north and St. Lawrence Island to the south. The basin contains up to 6600 feet (2000 m) of marine and non-marine Cenozoic strata similar to the Bristol Bay basin sequence to the southeast. Pribilof, St. George, Zhemchum, Navarin, and other similar but unnamed basins are elongate outer-shelf basins of broadly deformed and faulted marine deposits which parallel the northwest trend of the adjacent shelf margin. Whereas the inner-shelf Norton and Bering Sea basins represent large structural sags, many of the outer-shelf basins appear to be fault controlled.

(b) Hydrocarbon Potential

Petroleum prospects of the Bering Sea OCS region include: (1) the thick sections (basins) of Cenozoic and, in some areas, Cretaceous strata underlying broad areas of the continental shelf, (2) deformed Mesozoic rocks which underlie many of these basins, (3) domical and diapiric structures associated with the more deeply submerged (2000 m) Umnak Plateau area, and (4) thick masses of late Tertiary beds in summit basins along the crestal region of the Aleutian Ridge.

The most promising prospects are the thick accumulations of early Tertiary through Holocene beds that occur in the larger inner-shelf basins which underlie the shelf's major bays and gulfs (Norton and Bristol basins).

Many of the outer-shelf basins are underlain by folded Cretaceous and Jurassic strata which are not only prospective in themselves, but may have supplied hydrocarbons to overlying Cenozoic structures.

Other promising areas are the fairly large (as much as 30 x 80 km) summit basins of the 2200 km-long Aleutian Ridge. Roughly rectangular in shape and elongate parallel to the ridge, these structures are physiographic as well as geologic basins. The floors of two of them, neighboring Amukta (171.7°W) and Amlia (173°W) Basins, lie at a water depth of about 1000 meters and are underlain by a 3 to 4 km. thick late Tertiary sedimentary section. These basins are bordered by major normal faults. The infilled section is broadly folded as well as disrupted along high-angle growth faults.

(c) Geologic Hazards (See also Sec. II.A.4.a Intro.)

Seismic activity is minimal (zone 1) in all but the southernmost area (Fig. 50). Unconsolidated sediment cover is usually thin and known faults are fairly inactive. The nature and distribution of offshore permafrost are unknown, although patchy to continuous occurrences of highly variable relict thickness are most likely present in the mid to northern shelf areas.

(6) Chukchi Sea OCS

(a) General

The Chukchi Sea, off the Alaskan arctic coast, extends northward between Wrangel Island and Point Barrow to the edge of the continental shelf. The underlying Bering-Chukchi platform joins the Asian and North American continents. Water depths over the greater part of the shelf are generally less than 55 meters, with 40 meter depths commonly occurring 50 to 100 km off the Alaskan coast. Kotzebue Sound, a large, shallow coastal bay, dominates the southeastern Chukchi shoreline.

The Chukchi continental shelf is generally smooth, although Carsola (1954) characterized its outer margin as an area of minor topographic roughness. A broad topographic high shoals at 13 meters north of Bering Strait at about 70°30'N (Dietz, et al., 1964). To the west, a submarine canyon, Herald Canyon, extends northward along 173°W longitude to the outer continental margin. Beyond the shelf, the continental slope descends from 65m to about 180m water depth. A 100 mile-wide continental rise segment completes the continental margin sequence.

Ice activity has resulted in a patchy distribution of sediment types on the Chukchi Sea shelf. Most of the shelf is coated with a veneer of unconsolidated mud, sand and gravel derived from the mixing of poorly-sorted ice-rafted debris with normal shelf sediments. Thicker deposits of fine grained river-derived sediment have accumulated in the Kotzebue Sound, while along the adjacent Bering Strait, swift-moving currents have removed the unconsolidated sediment cover.

Subsurface Geology

Northern Chukchi Sea

A subsurface structural ridge, the Barrow arch, arcs northwest from Point Barrow, then southwest across the northern Chukchi Sea, dividing it into two distinct terrains.

A southward-thickening Mississippian-Jurassic sedimentary section extends between the Barrow arch and the north foothills of the Brooks Range and its offshore extension. These older strata are overlain by organic-rich early Cretaceous shales that are thought to have provided the oil trapped in the Prudhoe Bay field. Above these shale beds, younger Cretaceous strata contain a major resource of sub-bituminous and bituminous coal and at least some oil and gas on the North Slope of the Brooks Range. They and older rocks are bounded on the south by a major thrust fault zone.

Wrinkled carpet folds related to these faults dominate the structure of the Cretaceous beds in the southern part of the northern Chukchi Sea.

North of the Barrow arch, a thick sequence of bedded rocks dips northward from the arch to the continental slope. The upper beds in this sequence, presumably Tertiary in age, overlie older rocks of probable Cretaceous origin. Several large diapirs extend into the Cretaceous-Tertiary sequence; some pierce the entire section to the sea floor.

Southern Chukchi Sea -- Hope Basin

The Hope Basin is a broad structural depression that underlies a large portion of the Chukchi Sea south of 69°N latitude. The basin formed in early or mid-Tertiary time across a broad terrain underlain by locally altered and structurally complex Paleozoic to Mesozoic sedimentary and volcanic rocks. The basin fill is probably entirely clastic and of mixed marine and non-marine origin. A lower Tertiary sequence up to 5000 feet thick was later mildly faulted and folded. Subsequent deposition of a

Plio-Pleistocene sequence reached a maximum thickness of about one km. Figure 54 represents a schematic N-S stratigraphic cross-section through the Chukchi Sea OCS.

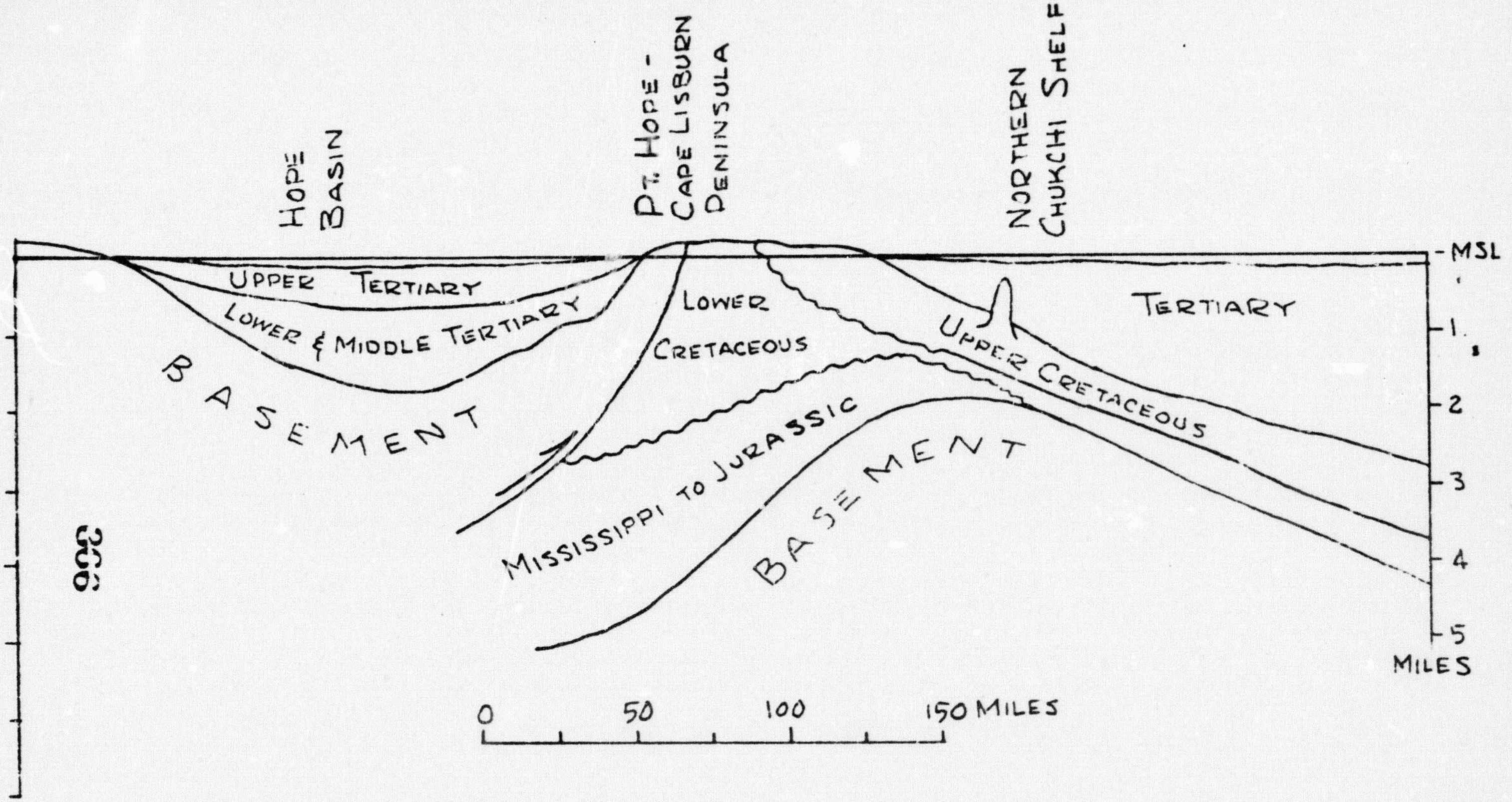
(b) Hydrocarbon Potential

The northern Chukchi Sea is underlain by some of the same geological features which co-joined to produce the super-giant oil and gas field at Prudhoe Bay and several lesser oil and gas fields in and near Naval Petroleum Reserve No. 4. Sedimentary deposits north of the Barrow arch may well attain thicknesses of 20,000 feet or more. The possibility that they may represent a late Cretaceous and Tertiary delta, combined with the presence of diapiric structures, makes the area attractive for petroleum exploration. The polar ice pack, however, may prevent adequate exploration for many years to come.

The presence of a regional arch, many smaller folds and numerous faults in the older sedimentary sequence, combined with a local erosional surface at the base of the younger sequence offer good oil and/or gas trapping potential within the Hope Basin.

(c) Geologic Hazards

Although much of the Chukchi Sea OCS has not been surveyed, potential geologic hazards related to seismicity,


HOPE BASIN
PT. HOPE - CAPE LISBURN PENINSULA
NORTHERN CHUKCHI SHELF
MSL
UPPER TERTIARY
LOWER & MIDDLE TERTIARY
BASEMENT
LOWER CRETACEOUS
TERTIARY
UPPER CRETACEOUS
MISSISSIPPI TO JURASSIC
BASEMENT
1
2
3
4
5
MILES
0
50
100
150 MILES

SCHEMATIC CROSS SECTION OF NORTH & SOUTH CHUKCHI SEA

Source: U.S. Geological Survey

Figure 54

bottom sediment stability, shallow subsurface conditions and submarine topography appear to be minimal. Coastal erosional and sediment transport regimes are active along some shoreline areas.

Bottom scour by sea ice along northern coastal areas will affect structure and pipeline placements. A relatively thick permafrost-active zone may exist within some offshore regions.

(7) Beaufort Sea OCS

(a) General

The Beaufort Sea shelf off Alaska is relatively narrow, varying in width from about 60 miles (97 km) in the west to approximately 30 miles (48 im) in the east. The shelf break lies between 50 and 70 meters water depth. Several submarine valleys dissect the shelf. The largest, Barrow Sea Valley trending northeastward off Point Barrow, extends across the shelf into the Arctic Ocean Basin.

Surface sediments on the Beaufort Sea shelf are similar to those described in the northern Chukchi Sea--a poorly-sorted mixture of mud, silt, sand and gravel. Gravel content is highest along the shelf outer margin (Rodeick, 1974).

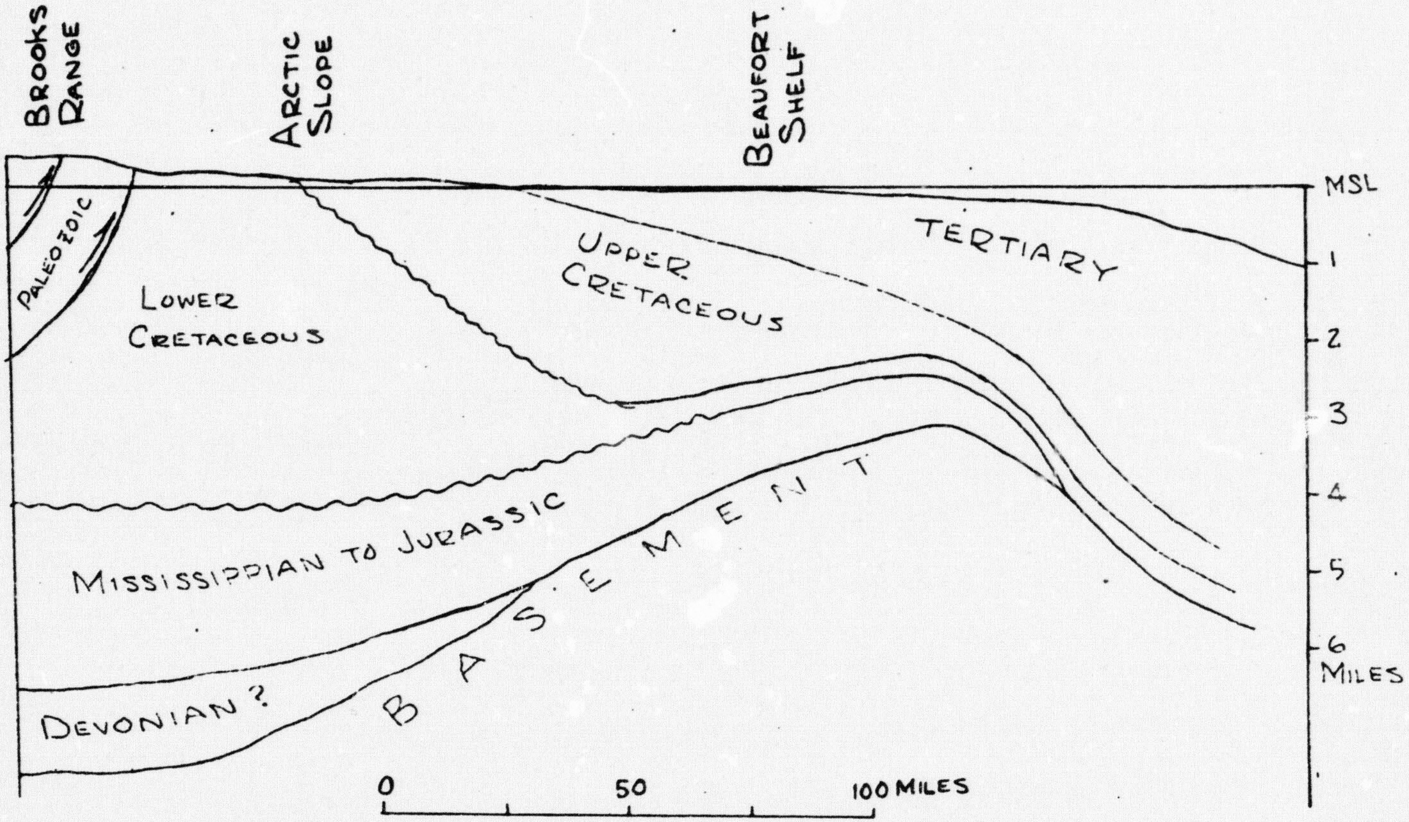
The seasonal input of sediment from coastal rivers complements shoreline erosional processes as the major sources of new sediment supplied to the Beaufort shelf. Much of this material enters the longshore drift regime and is slowly transported westward as part of the shifting system of sand bars and barrier islands that parallel the Beaufort coast. A similar, but eastward-flowing littoral drift occurs to the west of Point Barrow. Rex (1964) suggests that Barrow Sea Valley may provide the main channel for removal of the littoral sediment supplied to the Barrow area by the converging coastal currents.

Subsurface Geology

The Beaufort shelf and slope are underlain by a progradational sequence of Cretaceous marine and some non-marine sedimentary rocks that dips northward off the Barrow Arch with generally gentle dips. On the east, the Cretaceous rocks are overlain by Tertiary mixed marine and non-marine strata that have structure west of the mouth of the Canning River. East of the Canning, however, these rocks are thrown into folds with thousands of feet of structural relief and in some cases probably tens of miles of strike length. Figure 55 presents a schematic stratigraphic cross-section across the Arctic Coastal Plain-Beaufort Shelf.

(b) Hydrocarbon Potential

The Cretaceous rocks beneath the Beaufort Sea probably contain organic-rich shales at their base, as they do


Brooks Range
Arctic Slope
Beaufort Shelf
MSL
1
2
3
4
5
6
Miles
Paleozoic
Lower Cretaceous
Upper Cretaceous
Tertiary
Mississippian to Jurassic
Devonian ?
Basement
0
50
100 Miles

Schematic cross section from Brooks Range to Beaufort Shelf

Source: U.S. Geological Survey

onshore. In addition, sands higher in the section contain both oil and gas deposits near the coast onshore. The possibility also exists that some of the pre-Cretaceous rocks which contain oil at Prudhoe Bay may locally extend across the Barrow Arch and underlie the Beaufort shelf. While the Cretaceous and Tertiary rocks are of southern provenance and thicken seaward, the pre-Cretaceous rocks occur in general within shoreline facies along the Barrow Arch and thicken southward. Thus, a conservative projection of onshore data suggests that, if the prospective pre-Cretaceous rocks are present on the Beaufort shelf, they are of limited extent.

(c) Geologic Hazards

Potential geologic hazards occur primarily in the nearshore zone. Here, coastal erosion, migration of longshore bars and barrier islands, sea ice grounding and scour, and the nature of permafrost will affect the placement of pipelines and shore facilities.

b. Climate

(1) General Climatology and Seasonal Weather Patterns

Watson (1959) distinguished four climatic zones for Alaska based on the absence or presence of the maritime influence. Coastal areas in the Gulf of Alaska are in the maritime zone, characterized by small temperature variations, but high humidity, precipitation, cloud and fog frequencies. The mean annual temperature in this zone is about 40°F.

Waters off the western coast of Alaska lie in the transition zone, characterized by larger daily and seasonal temperature variations and less cloudiness, precipitation, and humidity than the maritime zone. Mean annual temperature in this zone is about 25-30°F.

Waters off northern Alaska (north of the Seward Peninsula) are in the Arctic climatic zone. Temperature variations are greater than the transitional zone and strong winds are common. Precipitation is very light. Ice covers these waters in the winter, and the mean annual temperature is about 15-25°F.

(2) Sky Cover and Visibility

Sky cover and visibility are extremely variable in Alaska, depending on the season and location. Table11 indicates conditions in representative Alaskan coastal towns. In general, the spring and summer months experience days of least visibility.

TABLE 11

SKY CONDITIONS

Station	Mean Monthly Variation of Sky Cover (Tenths)	Mean Number of Days Per Year Cloudy	Heavy Fog	Visibility Less Than 1/2 Mile
Anchorage	6 to 8	235	28	28
Homer	5 to 8	223	9	10
Barrow	5 to 9	188	65	
Yakutat	7 to 9	279	32	47
Cordova	7 to 9	262	12	18
Kodiak	7 to 8	185		30
King Salmon	6 to 9	244	33	35
Unalakleet	5 to 8	210	15	22
Nome	6 to 8	213	25	35
Kotzebue	6 to 8	204	20	31

SOURCE: Swift, W., et al. (1974).

Most of the Beaufort Sea is cloudy owing to the prevailing easterly wind from the Arctic Ocean. The cloud types are mainly low stratus and fog; cumuli forms are rare. Peak cloudiness occurs during August and September when the ocean is open (Swift, et al., 1974).

(3) Surface Wind Patterns

There is wide variation in average and extreme wind speeds in different areas of Alaska. Terrain and storm tracks play an important role in determining wind flow patterns in Alaska. Wind data for Alaska are quite limited and have been largely the byproduct of aviation weather observations (Watson, et al., 1971).

During the winter months it is not unusual to have winds in excess of 50 mph along the Arctic coast. Wind speeds greater than 70 mph have been experienced in winter months along the Arctic coast (Searby, 1968). These strong and rather persistent Arctic winds tend to parallel the coastline from Barrow to Barter Island, resulting in prevailing winds holding to easterly or westerly directions. Although wind speeds at Barrow average slightly less than speeds at Barter Island, Barrow has recorded maximum speeds grater than 100 mph in the month of January (Watson, 1959).

Searby (1969) reported that two types of strong surface winds occur in the Gulf of Alaska. One type is a very narrow band, produced by a strong pressure gradient, and reinforced by the venturi effect of deep narrow valleys. These winds are usually perpendicular to the coast and extend outward over water up to 30 miles from the coast. For example, with this type of wind, ships crossing the Copper River outlet will experience abrupt changes of speed upon entering and leaving the narrow band of wind. To our knowledge speed measurements for this type of wind have not been made. Estimates indicate that gusts of 100 to 120 mph are quite possible under extreme conditions.

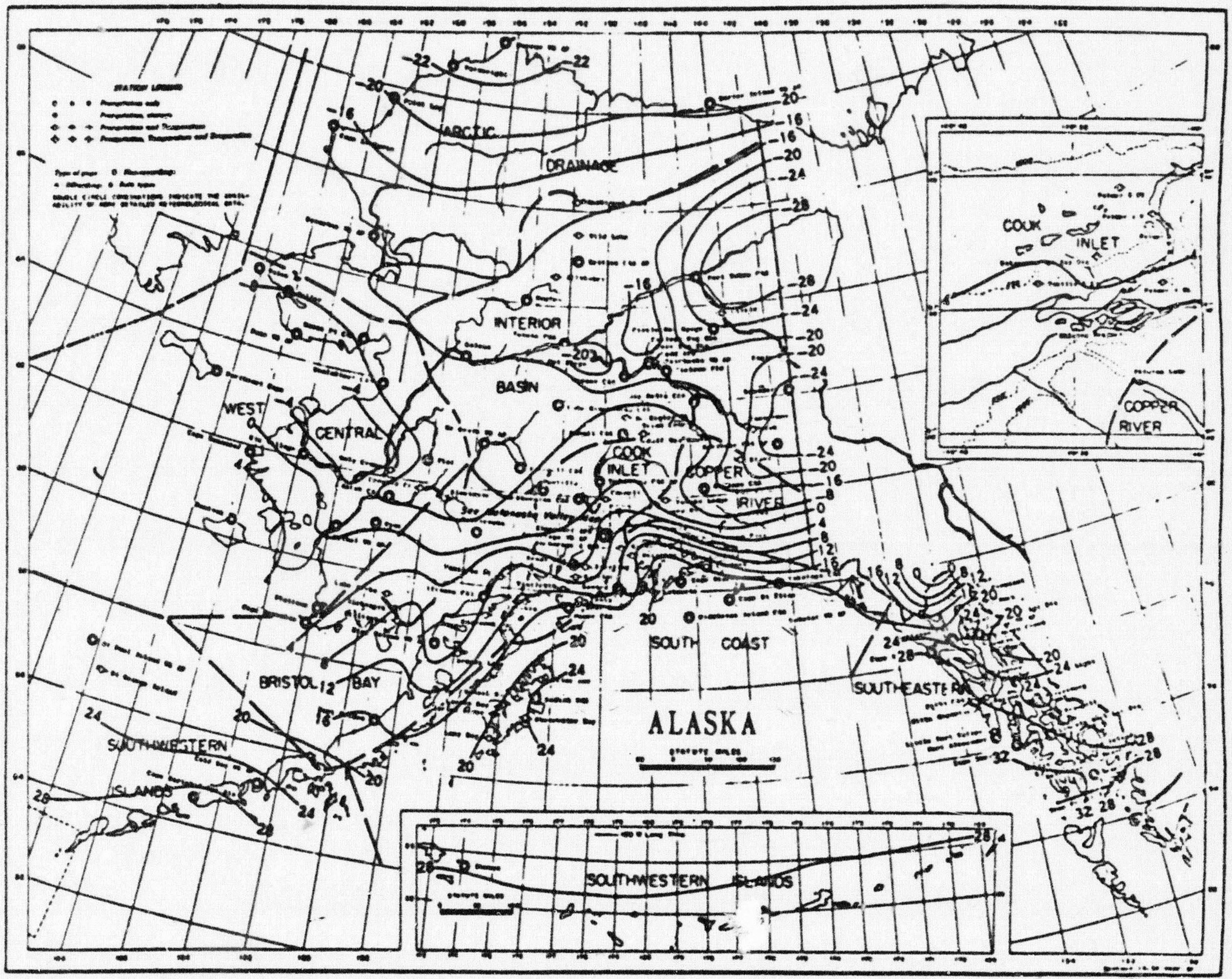
The other type of wind occurs with storms that frequent the Gulf of Alaska. These much broader bands of wind may persist for periods of one to three days with little change. Speeds over water will occasionally reach 75 to 100 mph.

(4) Air Temperatures

In the maritime zone the summer to winter range of average temperatures is from near 60 to 20's. In the transition zone, temperatures range from the low 60's to near zero, except for the cooler northern coastal region of the western-central division areas where the range is from the mid-50's to near 10 below zero. The Arctic Slope has a range extending from the upper 40's to 20 below zero (Searby, 1969).

Figure 56 illustrates in greater detail the mean minimum temperature for the month of January. Relative temperature experienced over adjacent waters can be estimated by extrapolation.

Mean Minimum Temperature (°F.), January


ARCTIC
DRAINAGE
INTERIOR
BASIN
WEST
CENTRAL
COOK
INLET
COPPER
RIVER
SOUTH COAST
SOUTHEASTERN
BRISTOL BAY
SOUTHWESTERN
ISLANDS
ALASKA
SOUTHWESTERN ISLANDS
-22
-20
-16
-24
-28
-8
-4
0
4
8
12
16
20
24
28
32

Based on period 1931-52

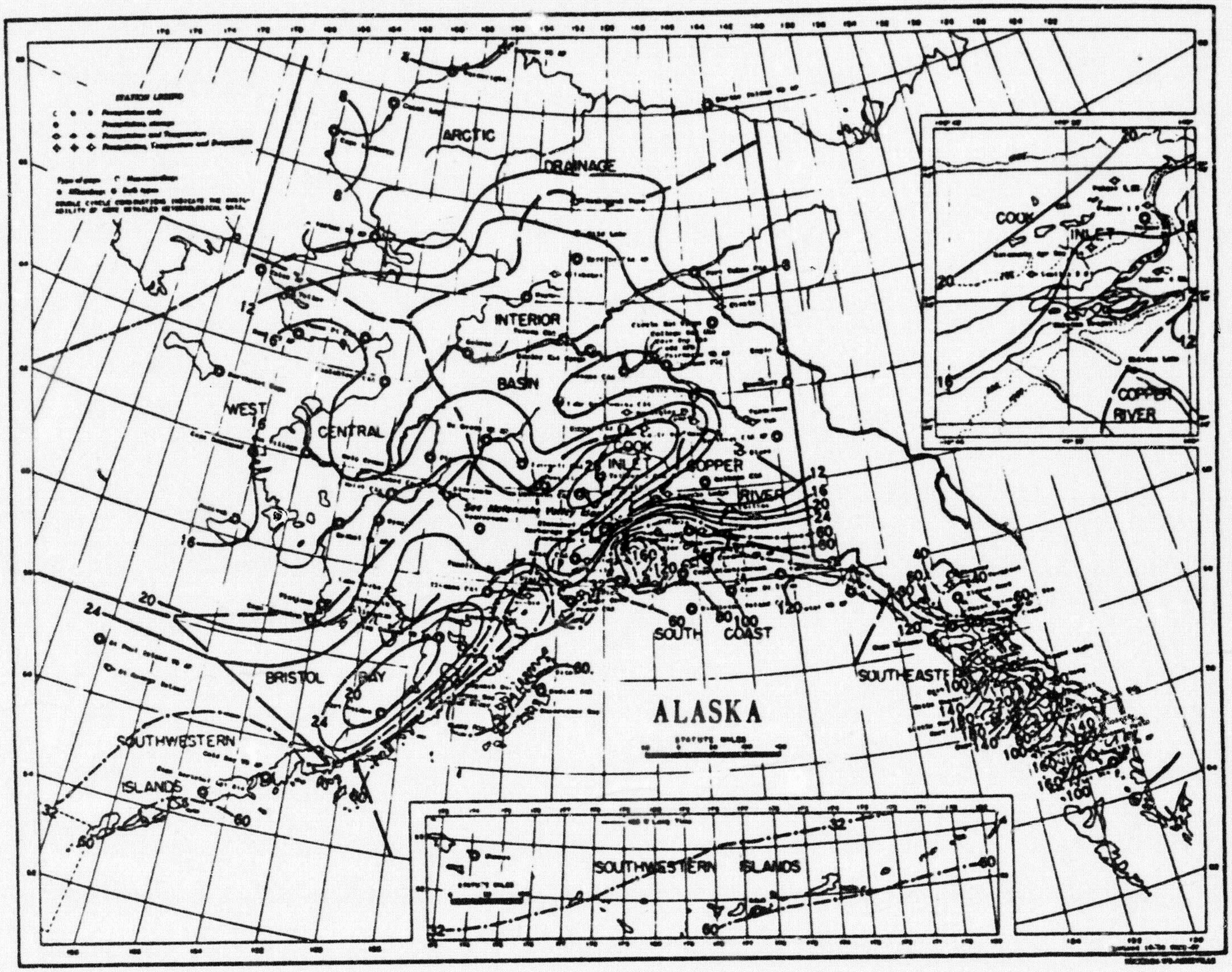
Figure 56 Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas. From Searby, 1968.

(5) Precipitation

Offshore precipitation in Alaska appears to be inversely related to the latitude, although local variations such as coastal topography and water masses are important. Figure 57 indicates the mean annual precipitation of continental Alaska. Over 200 inches of moisture fall in parts of the southwestern panhandle which is in the maritime climatic zone. Farther north and west, precipitation amourts decrease rapidly, being very slight in the transitional and arctic climatic zones. Figure57 clearly shows the influence of coastal topography on precipitation in Bristol Bay. The Aleutian Range acts as a moisture barrier to the moisture-laden air masses in the Gulf of Alaska, resulting in a zone of low rainfall in Bristol Bay. Due to a lack of precipitation measurements at sea, offshore precipitation may be quite different than onshore.

(6) Storms

The Gulf of Alaska and the area south of the Aleutian chain are well-know as areas of cyclogenesis (storm origin). Storms are frequent and of high intensity, producing large quantities of precipitation and very strong winds. Figure 58 shows average sea level pressure patterns and major storm tracks for winter and summer months, respectively. The intense gradients between the Aleutian low pressure cell and the Arctic high pressure cell during winter generates the very strong surface winds. As a result of these



Mean Annual Precipitation, Inches

ARCTIC
DRAINAGE
INTERIOR
BASIN
WEST
CENTRAL
COOK
INLET
COPPER
RIVER
SOUTH
COAST
BRISTOL
BAY
SOUTHWESTERN
ISLANDS
SOUTHEASTERN
ALASKA
COOK
INLET
COPPER
RIVER
SOUTHWESTERN ISLANDS
8
12
16
20
24
32
40
60
80
100
120
140
160

Figure 57. **Isolines are drawn through points of approximately equal value. Caution should be used in interpolating on these maps, particularly in mountainous areas.** From Searby, 1968.

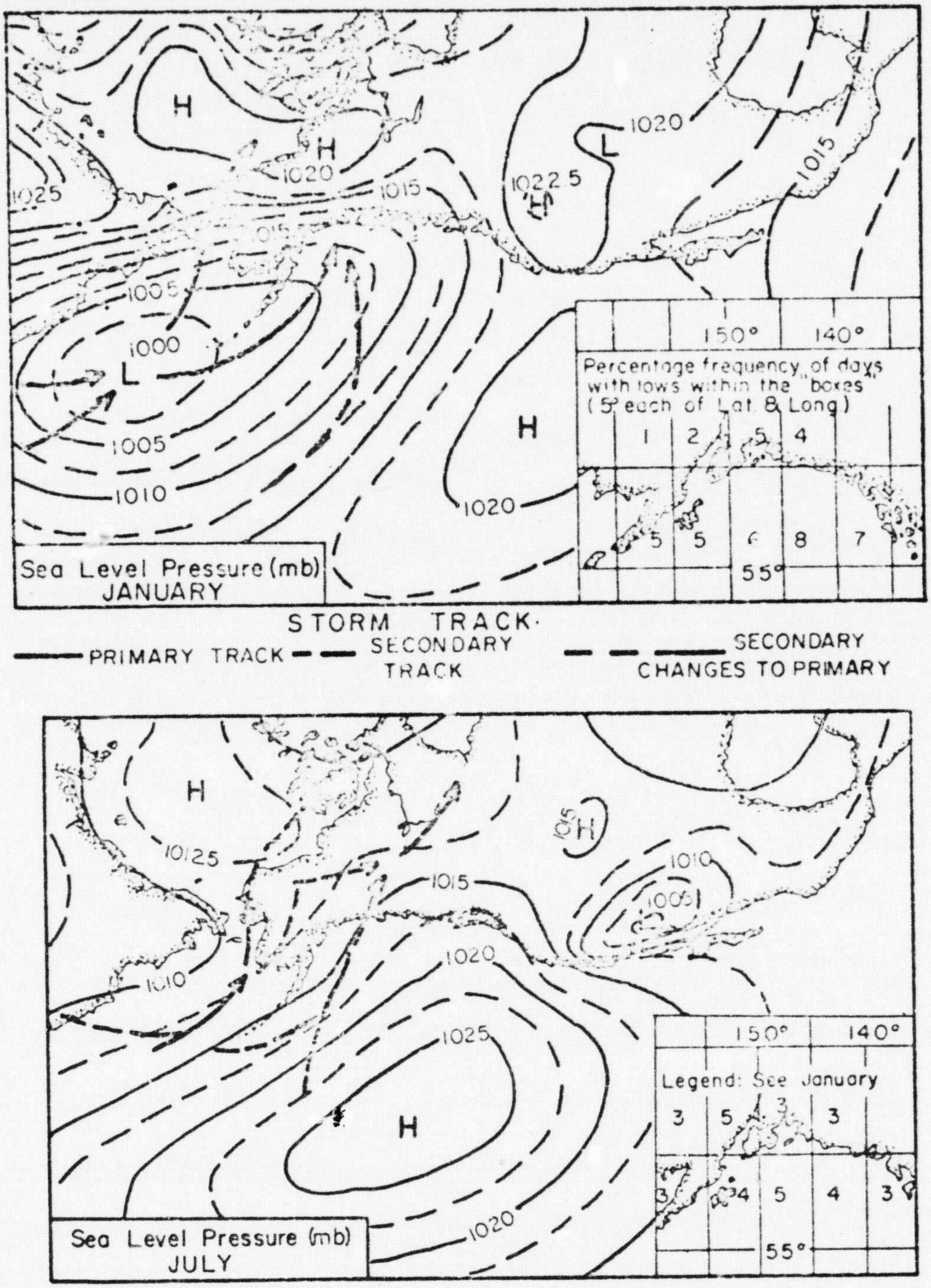

H
H
1020
1025
1015
1015
1005
1000
L
1005
1010
1022.5
H
L
1020
1015
H
1020
150°
140°
Percentage frequency of days with lows within the "boxes" (5° each of Lat. & Long.)
1 2 5 4
5 5 6 8 7
55°
Sea Level Pressure (mb) JANUARY
STORM TRACK
PRIMARY TRACK
SECONDARY TRACK
SECONDARY CHANGES TO PRIMARY
H
1012.5
1010
1015
H
1010
1005
1020
1025
H
1020
150°
140°
Legend: See January
3 5 3 3
3 4 5 4 3
55°
Sea Level Pressure (mb) JULY

Figure 58. Average sea level pressure pattern and major storm tracts, January and July (From Searby, 1969).

conditions, the Gulf of Alaska is generally considered to be one of the stormiest places in the northern hemisphere. During the summer, pressure gradients decrease markedly as the Aleutian low pressure area nearly dissipates.

The Bering Sea area is often influenced either by storms originating in the Bering Sea or those which move northeasterly from storm centers in the Aleutian Islands. Farther north, in the Chukchi Sea, high-velocity winds accompany passing storms.

Waters off the northern coast of Alaska are not generally areas of storm generation, although storms generated elsewhere may pass through this area. As indicated by Searby (1971) surface winds are extremely persistent, flowing predominantly to the east.

c. Physical Oceanography

(1) Surface Sea Temperatures

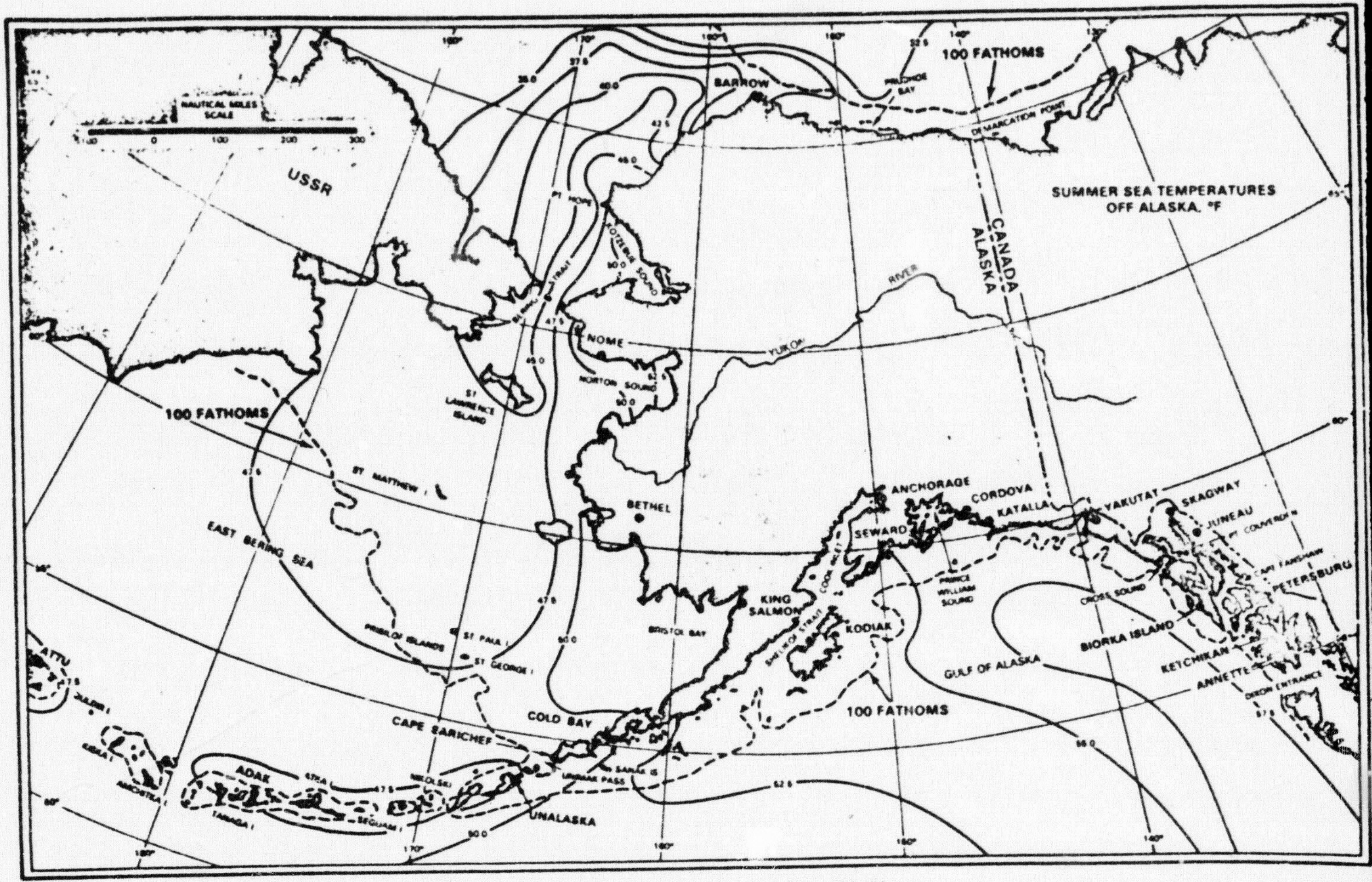
Sea surface temperatures in Alaska waters reflect surface circulation patterns to a large extent. In general, offshore surface temperatures decrease as the water flows northward and westward in the Gulf of Alaska. Temperatures range from about 45°F. (winter) to 55°F. (summer) in the western Gulf (U.S. Dept. of Commerce, 1961). Temperatures decrease by 5 to 8°F. as the water flows past the Aleutian Islands into the Bering Sea.

Within the Bering Sea, water temperatures range from 30°F. (near the winter ice cover), about 50°F. near Bristol Bay in the summer, to less than 40°F. north of Point Hope in the summer. Figures 59 and 60 illustrate Alaska water temperatures in summer and winter, respectively. Local variations are common due to river runoff, topography and other factors.

(2) Salinity

Salinity, like temperature, is associated with the ocean circulation patterns. Highest surface salinities (32.7^{o}/oo) are found in the central Alaska gyre (the major circulatory current system in the Gulf of Alaska). Closer to shore, salinities decrease considerably, particularly along the western shore of the Gulf of Alaska where salinities as low as 21.7^{o}/oo have been reported (Robinson, 1957). These minimum salinities are attributed to abundant precipitation and continental runoff.

In the Bering Sea salinities decrease progressively northward from the Aleutian Islands. Much of this decrease results from Bristol Bay runoff into coastal Gulf of Alaska waters. To a lesser extent, ice melt in the spring and a greater rate of precipitation contribute fresh water to the Bay. As the water flows northward towards the Chukchi Sea, surface salinity continues to decrease. Bialek (1966) indicated maximum salinities of 31.0^{o}/oo in the Chukchi Sea and less than 27.0^{o}/oo in the Beaufort Sea off Point Barrow. These conditions produce a distinct separation between the less-saline, less dense surface



100 FATHOMS
BARROW
PRUDHOE BAY
DEMARCATION POINT
NAUTICAL MILES SCALE
100 0 100 200 300
USSR
SUMMER SEA TEMPERATURES OFF ALASKA, °F
CANADA
ALASKA
PT HOPE
KOTZEBUE SOUND
BERING STRAIT
YUKON RIVER
NOME
NORTON SOUND
ST LAWRENCE ISLAND
100 FATHOMS
ST MATTHEW I
BETHEL
EAST BERING SEA
ANCHORAGE
CORDOVA
KATALLA
YAKUTAT
SKAGWAY
JUNEAU
PT COUVERDEN
CAPE FANSHAW
PETERSBURG
SEWARD
COOK INLET
PRINCE WILLIAM SOUND
KING SALMON
SHELIKOF STRAIT
KODIAK
CROSS SOUND
BIORKA ISLAND
KETCHIKAN
ANNETTE
DIXON ENTRANCE
GULF OF ALASKA
PRIBILOF ISLANDS
ST PAUL I
ST GEORGE I
BRISTOL BAY
100 FATHOMS
ATTU
COLD BAY
CAPE SARICHEF
ADAK
ATKA
NIKOLSKI
UNIMAK PASS
SANAK IS
UNALASKA
KISKA I
AMCHITKA
TANAGA I
SEGUAM
37.5
40.0
42.5
45.0
47.5
50.0
52.5
180°
170°
160°
150°
140°
130°
70°
65°
60°
55°

FIGURE 59. SUMMER SEA TEMPERATURES OFF ALASKA (°F) (Battelle, 1974)

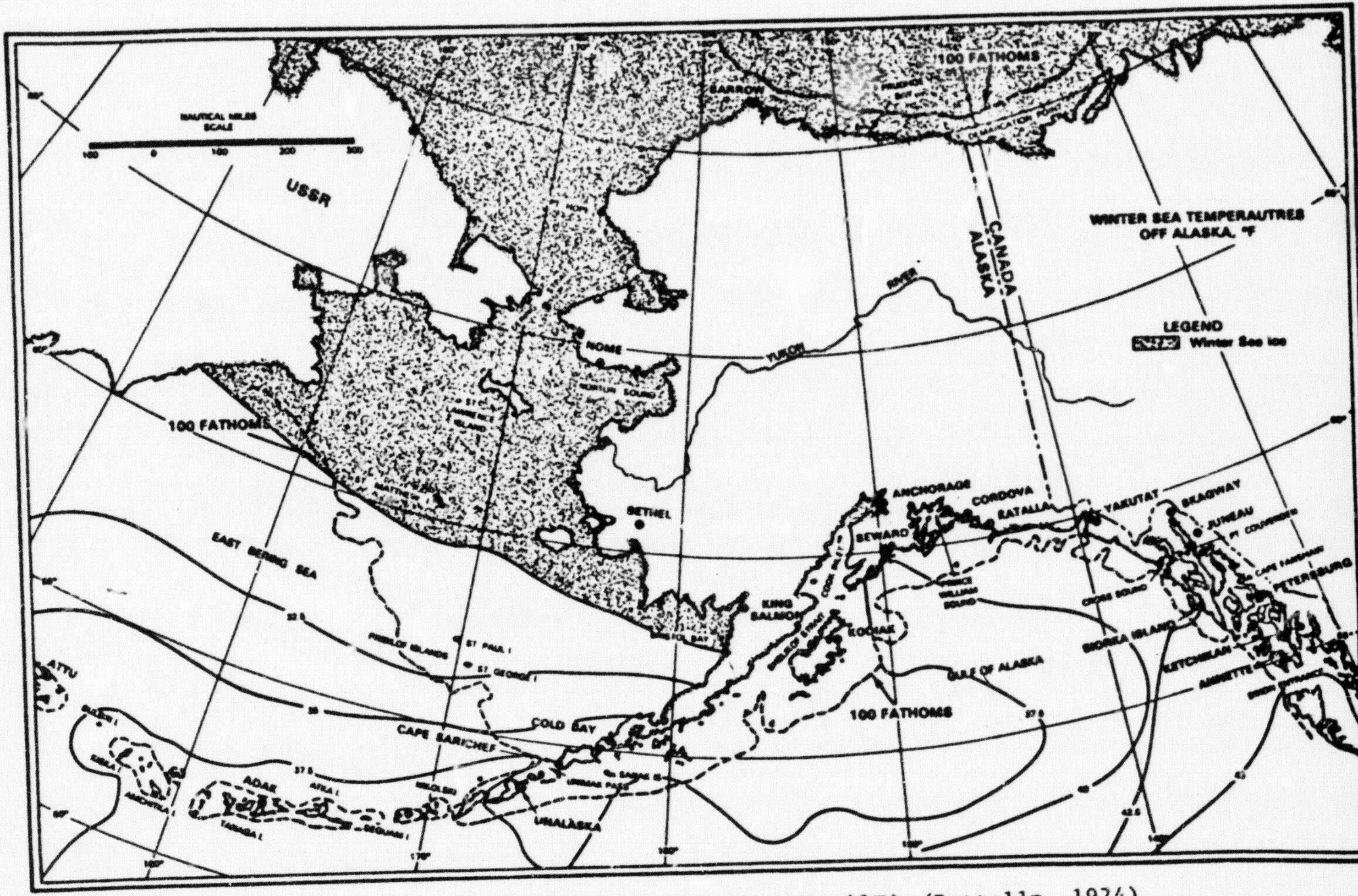

NAUTICAL MILES
SCALE
USSR
BARROW
100 FATHOMS
CANADA
ALASKA
WINTER SEA TEMPERAUTRES
OFF ALASKA, °F
LEGEND
Winter Sea Ice
YUKON
RIVER
NOME
NORTON SOUND
BETHEL
100 FATHOMS
EAST BERING SEA
ANCHORAGE
CORDOVA
KATALLA
YAKUTAT
SKAGWAY
JUNEAU
PETERSBURG
SEWARD
PRINCE WILLIAM SOUND
KING SALMON
KODIAK
CROSS SOUND
SITKA ISLAND
KETCHIKAN
ANNETTE
GULF OF ALASKA
100 FATHOMS
PRIBILOF ISLANDS
ST PAUL I
ST GEORGE I
ATTU
COLD BAY
CAPE SARICHEF
ADAK
ATKA I
UNALASKA
UNIMAK PASS
SANAK IS
37.5
35
32.5
40
42.5

FIGURE 60. WINTER SEA TEMPERATURES OFF ALASKA (°F) (Battelle, 1974)

382

waters and the much more saline sub-surface waters. Vertical mixing is therefore grately reduced except for periods of high turbulence.

(3) Surface Circulation

Offshore circulation in Alaska waters begins with the "West Wind Drift", a slow eastward-flowing current between 40° and 50° north latitude (Fig. 61). As this current encounters the North American coast it branches to the north and south. The northern branch becomes the Alaska Current, flowing counterclockwise and roughly parallel to the arcing coastline. Part of this current enters the Bering Sea through the Aleutian Islands, although the major portion of flow continues on and rejoins the West Wind Drift at the tip of the Aleutian Islands.

This description is rather simplistic; the actual circulation patterns are quite complex. Meanders and reversals often occur due to weather conditions, bathymetry, and nearshore topography. Plakhotnik (1964) estimated average current speeds as follows: 0.1 to 0.2 knot in the West Wind Drift; 0.3 to 0.4 knot in the western Gulf of Alaska; increasing to 1.0 to 1.5 knots along the northern Gulf coast and the Aleutian Islands.

Offshore Alaskan currents have been measured only sparsely. Logs of ships' drift, geostrophic calculations (based on density gradients), and theoretical wind-stress calculations have been used to infer general circulation patterns. Additional information has been

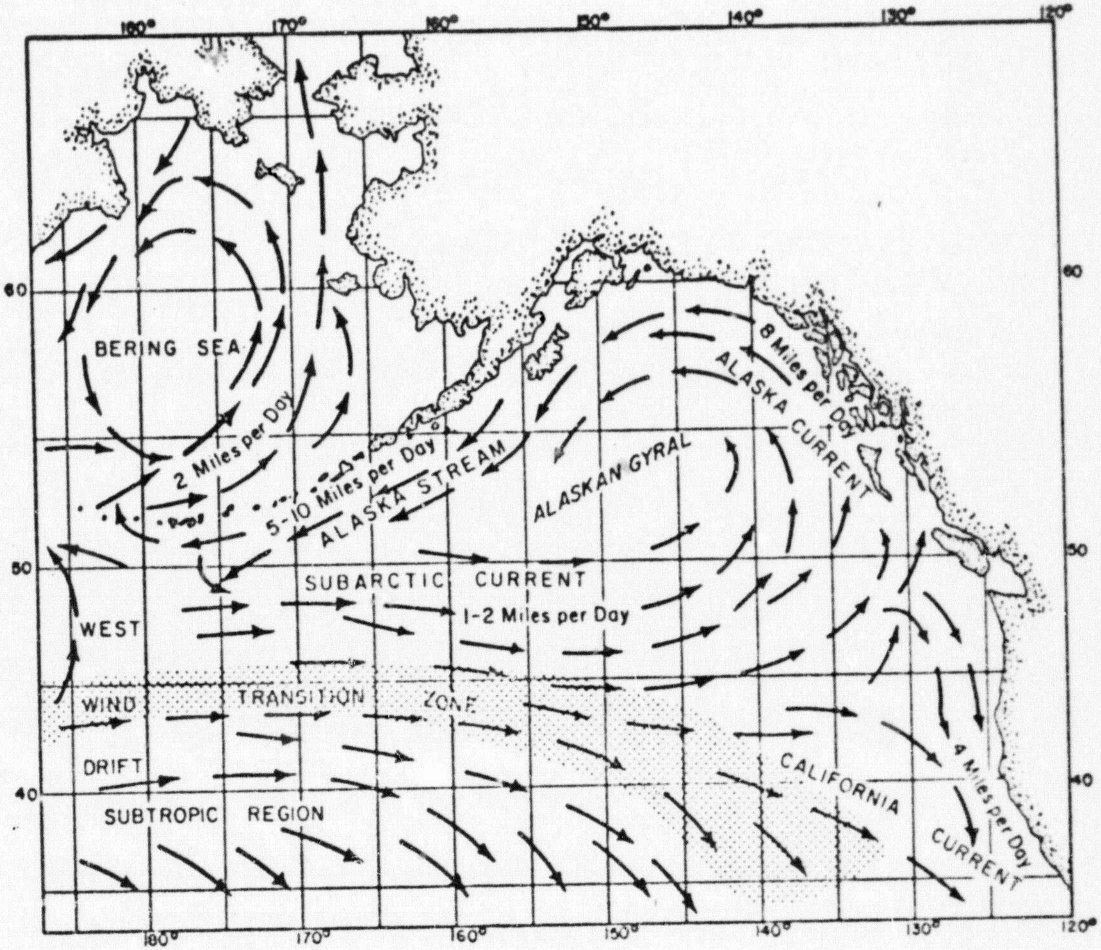

180°
170°
160°
150°
140°
130°
120°
60
50
40
BERING SEA
2 Miles per Day
5-10 Miles per Day
ALASKA STREAM
ALASKAN GYRAL
8 Miles per Day
ALASKA CURRENT
SUBARCTIC CURRENT
1-2 Miles per Day
WEST
WIND
TRANSITION
ZONE
DRIFT
SUBTROPIC REGION
CALIFORNIA
CURRENT
4 Miles per Day

Figure 61. General circulation, North Pacific Ocean--1 mi./day ≅ 2 cm./sec; 50 cm./sec. ≅ 1 knot (adapted from Dodimead, Favorite, Hirano 1962).

derived from drift bottle experiments which have been performed sporadically for many years.

Forces behind the offshore circulation in the Gulf of Alaska are the geostrophic (due to ocean pressure gradients and the earth's rotation), and wind-stress components. Geostrophic calculations based on numerous hydrographic cruises have presented fairly consistent estimates of current speed and direction. Current speeds in the main Alaskan gyre are rather slow as estimated by this method, but increase in the northern and western areas of the Gulf.

The stress of the wind blowing over the water can reinforce the geostrophic flow, particularly during the winter months when strong winds are associated with the Aleutian low pressure system. Roden (1969) determined that the winter intensification of current flow is very closely associated with the low pressure field. This added wind stress alone may produce current velocities in excess of 0.4 kt (20 cm/sec.) near the continental slope.

Of the water which flows into the Bering Sea from the Gulf of Alaska, a portion flows through Unimak, Amutka and Amchitka Passes. This water mixes with eastward flowing waters along the northern shores of the Aleutians. The resulting mixture, augmented by Bristol Bay outflow and the Kuskokwim and Yukon Rivers, moves north until it branches near St. Lawrence Island. One branch moves to the west along the shores of Kamchatcha while the other branch flows through the Bering Sea Strait into the Chukchi Sea. According to N.A.S. (1970), about 20% of the Bering Sea inflow into the Chukchi Sea is a mixture of sea water and terrestrial runoff. (The remainder is Bering Sea water, ice melt water, and residual water of the Chukchi Sea.)

Circulation in the Chukchi Sea appears to be sluggish, moving generally counterclockwise. Current speeds vary considerably, depending on river runoff, ice melt and winds. Water flows northeastward until it reaches Point Barrow. Here it encounters the westerly flowing Beaufort Sea currents, and the resultant flow is offshore. For the most part, currents in the Arctic region are extremely variable, in both speed and direction, depending on the local winds.

(4) Tides

The tide (if considered as a shallow wave) moves in a northwesterly direction in Alaska waters. The physiography of Alaska tends to magnify the effect of tidal heights (Fig. 62). For example, triangular bays (such as Bristol Bay and Cook Inlet) "funnel" the tide towards the apex, creating very large tidal heights. Ranges greater than 20 and 30 feet have been reported at Bristol Bay and Cook Inlet, respectively. The large tidal ranges play an important and conspicuous part in the circulation and mixing processes, especially along the Gulf of Alaska and Bristol Bay shores.

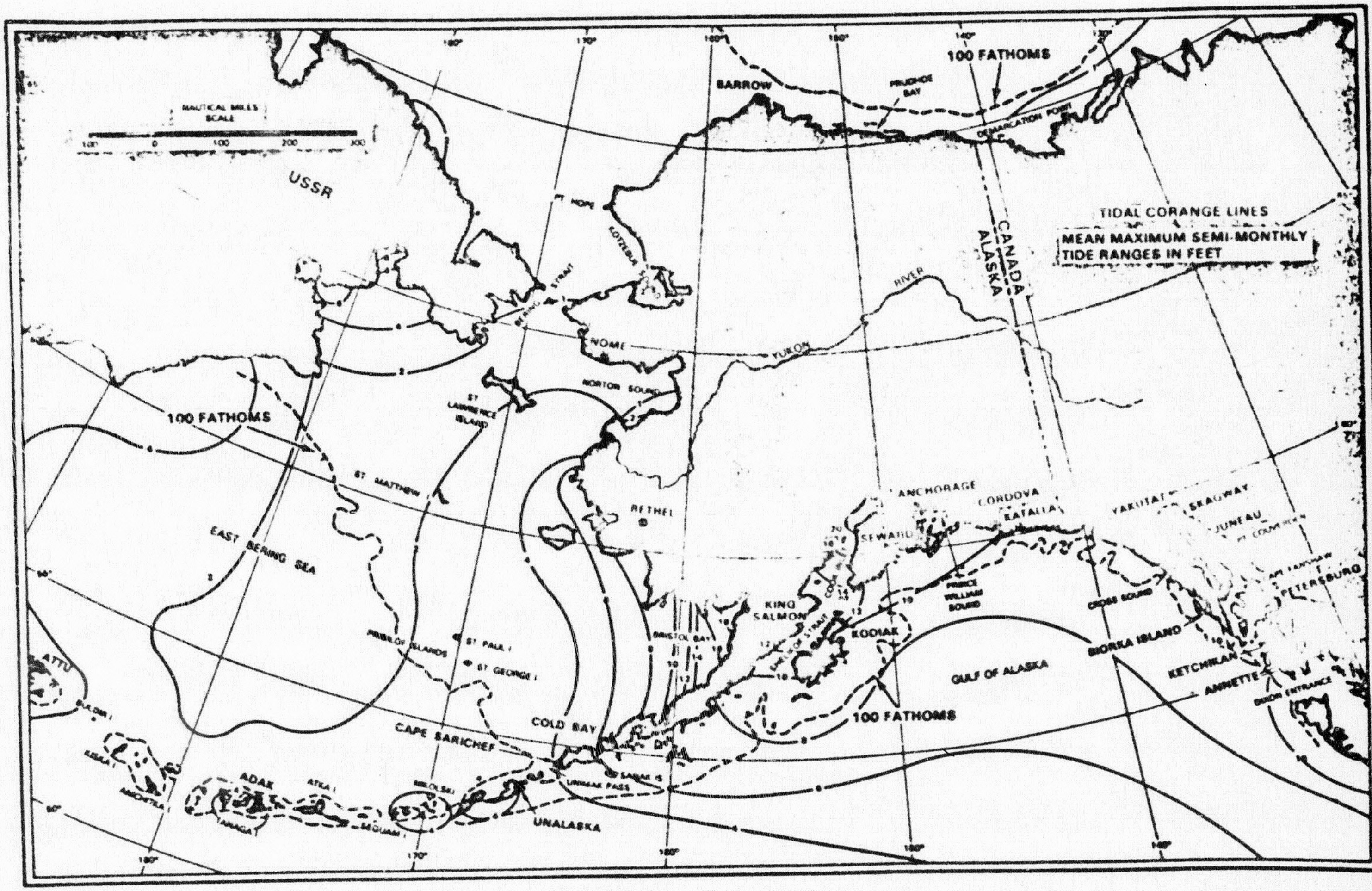

NAUTICAL MILES
SCALE
100 0 100 200 300
USSR
BARROW
PRUDHOE BAY
100 FATHOMS
DEMARCATION POINT
PT HOPE
KOTZEBUE SOUND
BERING STRAIT
CANADA
ALASKA
TIDAL CORANGE LINES
MEAN MAXIMUM SEMI-MONTHLY
TIDE RANGES IN FEET
YUKON
RIVER
NOME
NORTON SOUND
ST LAWRENCE ISLAND
100 FATHOMS
ST MATTHEW
BETHEL
EAST BERING SEA
ANCHORAGE
CORDOVA
KATALLA
YAKUTAT
SKAGWAY
JUNEAU
SEWARD
PRINCE WILLIAM SOUND
PETERSBURG
KING SALMON
COOK INLET
SHELIKOF STRAIT
KODIAK
BRISTOL BAY
PRIBILOF ISLANDS
ST PAUL I
ST GEORGE I
CROSS SOUND
BIORKA ISLAND
KETCHIKAN
ANNETTE
DIXON ENTRANCE
GULF OF ALASKA
ATTU
COLD BAY
CAPE SARICHEF
100 FATHOMS
ADAK
ATKA I
AMCHITKA
KISKA I
TANAGA I
SEGUAM I
UNIMAK PASS
SANAK IS
UNALASKA
180°
170°
160°
150°
140°
130°
60°
50°

Figure 62 TIDAL CORANGE LINES (Battelle, 1974)

Tide ranges decrease rapidly north of Bristol Bay. Beyond the Bering Strait tide ranges are generally less than one foot during ice-free periods. Very small ranges occur during the winter months when ice covers the ocean surface. Of greater consequence is the set-up, or surge, (rise in water level) caused by rapid decreases of barometric pressure or onshore winds. The changes in sea level due to these latter forces can be as much as five feet (Swift, et al., 1974).

(5) Sea and Swell

Locally generated sea tends to be the dominant form of wave motion in Alaskan waters. Sea, as opposed to swell, is irregular in height and period. Wave crests tend to be peaked and induce considerable motion to ships and other floating objects. Swell, generated outside Alaskan waters, undergoes modification by large storms in the Alaskan area.

Autumn appears to be the stormiest season in the Gulf of Alaska and therefore produces the roughest seas. In spite of the severity of the storms and the intensity of the winds, no waves greater than 30 feet have been observed (Searby, 1969). A recent study (G.A.O.C., 1973) suggests there is less than 25% probability of offshore waves exceeding 14 feet in the Gulf of Alaska.

Rough sea conditions occur much less frequently in the Bering Sea than in the Gulf of Alaska. The eastern Aleutian Islands experience considerably less severe wave conditions than the islands farther offshore. Seas in the Chukchi and Beaufort Seas are relatively calm as wind influence over the water surface is limited by distance (fetch).

In winter months, the frequencies of wave heights greater than 5 feet are about twice those experienced during summer months.(U.S. Dept. of Commerce, 1961). Ice coverage extends just south of 60° north latitude, so that no waves occur in the northern Bering Sea and the Chukchi and Beaufort Seas during this season.

d. The Biological Environment

Marine biological environments of Alaska are grouped by their ocean or sea of origin. The groupings, based on natural separations, are the Gulf of Alaska, the Bering Sea, and the Arctic Ocean. Where information is available, each area will be discussed individually.

(1) Phytoplankton

Marine phytoplanton production in all areas of Alaska is markedly seasonal. In these high latitudes, primary productivity (phytoplankton growth) is directly related to available light. Maximum production occurs during the arctic summers when daylight is nearly continuous.

In addition to sunlight, several other physical parameters are important to primary production. If the depth of surface layer mixing is so great that the phytoplankters are below a specific level of light, their respiration requirements may exceed the organic matter they produce. This results in a net energy loss and the population decreases. However, if the wind-mixed layer (or ocean bottom) is less deep than the "critical depth" (Sverdrup, 1953) mentioned above, photosynthesis provides a net gain and the phytoplankton population increases, providing nutrients are not limiting.

The few studies completed within the Gulf of Alaska indicate several general conclusions. Total annual primary production may be two to four times greater on the continental shelf than in the open ocean (Cooney, 1972), although Larrance (1971) indicated the difference between coastal and open ocean values may not be so large. Comparisons between different years are of value, as they define a range of annual fluctuations. However, inter-year fluctuations do not provide representative productivity estimates. For example Gulland (1972) pointed out that productivity estimates in the open ocean (Ocean Station P) in 1969 are only one-half the 1960-1965 values.

The Aleutian Islands and the Bering Sea are shown to be regions of high productivity during the summer. Annually, production estimates generally decrease to the north. Larrance (1971) found annual production in the southern Gulf of Alaska to be about 80 to 100 g C/m^2. Gulland (1972) estimated annual production to be about 150 g C/m^2

along the coastal strip. These values compare with extremely high production (over 600 g C/m^2) in the southeastern part of the Bering Sea (Azova, 1964). Production decreases significantly farther offshore in the Bering Sea and Chukchi Sea. Primary production is very low in the Arctic Ocean as estimates of less than 1 g $C/m^2/yr$ have been reported. These very general estimates may be characteristic of a large scale production pattern, but much higher or lower values may occur in specific areas.

A unique community of phytoplankton occurs within the diffuse lower layers of first-year sea ice. These plants live in or on the ice, actively growing when solar radiation is present. This ice algae reaches a growth peak near the end of May in the arctic, then declines abruptly as the ice breaks up in summer.

(2) Zooplankton

More extensive investigations of zooplankton populations of the North Pacific have been made than of the phytoplankton populations. A direct relationship exists between the "grazers" (herbivorous zooplankton) and the marine phytoplankton. In general, peaks of zooplankton abundance closely follow peaks of phytoplankton abundance.

Zooplankton, as the name implies, are carried by the current, but they can undergo significant daily vertical migrations (to 800 meters).

One consequence of zooplankton migration appears to be the "hibernation" of zooplankton in the deep oceanic waters during winter when there is essentially no phytoplankton on which to graze. When the spring phytoplankton "bloom" occurs, oceanic zooplankton migrate upward to forage. However, in the shallow coastal waters of the Gulf of Alaska and the Bering Sea, there is no deep water to harbor the zooplankton, and as a result, there is a considerable lag between phytoplankton-zooplankton abundance peaks.

The seasonal abundance of zooplankton in the Gulf of Alaska follows the pattern of phytoplankton. During the winter, zooplankton biomass is at its lowest. In March, grazers appear in the surface waters, increasing in number until reaching a peak in late May. From data collected at Ocean Station P, the peak standing stock of zooplankton was about 175g per 100m^3 of water (Le Brasseur, 1965).

Zooplankton studies in the Bering Sea have indicated that large variations in abundance occur. Meshcheryzkova (1970) suggested the degree of penetration of North Pacific water into the Bering Sea was responsible for this variability. Zooplankton were also found to be more abundant in clearer offshore waters than in the more turbid waters of Bristol Bay. Copepods make up 70 to 90 percent of the total Bering Sea zooplankton (Mednikou, 1960).

Water flow is north from the Bering Sea, such that English (1966) stated that the marine environment of the eastern Chukchi Sea is dominated by the flow of Pacific Ocean water moving through the Bering Strait. Therefore, zooplankton of the Chukchi and Beaufort Seas generally include species from the Bering Sea. Several exceptions are the nearshore lagoon areas which exhibit freshwater or brackish-water zooplankton forms (Johnson, 1966).

(3) Benthic Biota

Although relatively little information is available on benthos of Gulf of Alaska waters, studies have shown considerable differences in biomass, particularly between areas near land masses and from under central ocean gyres (Cooney, 1972).

Semenov (1965) found 108 species of benthic organisms on the continental shelf and upper slope of the Gulf of Alaska. The highest standing stocks (120-520 g C/m^2; average of 180 g /m^2) occurred in rocky areas and those of gravel and pebbles. The other substrates had similar biomass estimates of 40-70 g /m^2. The continental slope average was 19 g /m^2.

Considerable variation was encountered due to depth, currents, substrate, and other factors. High biomass estimates appeared to be related to strong currents.

The Bering Sea benthos also varied spatially. Neiman (1963) reported very low standing crop estimates for Bristol Bay (less than 10 g/m^2)

but much higher ones over the continental shelf to the north of Bristol Bay (over 100 g/m^2).

Gulland (1972) discussed the value of benthos as fish food. He concluded that although the Bering Sea biomass of benthos exceeds that of the Gulf of Alaska, the biomass of the latter area is about three times more useful as fish food than that of the Bering Sea.

The benthos of the Chukchi and Beaufort Seas are comparable in biomass and numerical density to temperate regions (Arctic Institute of North America, 1974), in spite of a much more rigorous environment. Carey, et al. (1974) found anneiids, molluscs, and arthopods, in that order, to be the dominant organisms. These authors found that the numerical density of organisms increased offshore, reaching a peak density at 700 meters (4,344 organisms /m^2). In contrast, the biomass was greatest (227 g/m^2) on the continental shelf at a depth of 140 meters and lowest at 700 meters (4.1 g/m^2). This implies that much larger organisms are found on the upper continental shelf than on the slope.

Quantitative studies of benthos of the Chukchi Sea off Siberia indicated a biomass of 25-30 g/m^2 at depths of 8 meters. In depths of 30 to 50 meters, the biomass averaged 214 g/m^2, with polychaetes being the dominant group (by weight) followed by arthopods and molluscs (Zenkevitch, 1963).

(4) Active Swimmers - Nekton

Alaskan waters harbor an immense number of active swimmers, including invertebrates, fish, mammals and diving waterfowl. The majority of information concerns commercial species of finfish and shellfish. These species include salmon, halibut, and, although not nekton, shrimp, king and tanner crabs. Other species, harvested in very large volumes, but principally by foreign fleets, are herring, pollock and Pacific Ocean perch. Because of high costs of labor, materials, and services, Alaskan fisheries have concentrated on high unit value species such as those listed above. Consequently, other species of nekton have not been actively exploited or investigated.

The Arctic Ocean can generally be disregarded in terms of significant commercial fisheries at the present time because of the rigorous environment.

Salmon and herring are the two principal pelagic species harvested in both the Gulf of Alaska and the Bering Sea. Demersal fish (living on or near the bottom) make up a small proportion of the Alaskan catch. Table 12 illustrates the magnitude (and relative importance) of Alaska's fisheries from 1961 to 1969, as well as fluctuations in the catches. These fluctuations are due to both biological and economic conditions.

Each species of fish characteristically inhabits a specific environment, delineated by depth, currents, temperature, forage, and other factors. Therefore, estimates of fish abundance must include a description of

TABLE 12 Total Fisheries Catches from the Northeast Pacific (Thousand Metric Tons)

Species		1961	1962	1963	1964	1965	1966	1967	1968	1969
Demersal fish	Alaska			14	11	15	14	12	6	10
Salmon	Total[a]	436	398	419	383	428	441	397	375	
	Alaska	120	126	101	142	125	152	63	130	100
Herring	USA	25	19	18	24	16	11	8	6	
	Alaska[b]			14	22	12	9	5	4	6
King Crab	USA	20	24	36	39	60	72	58	39	
	Alaska	20	24	36	39	61	72	59	37	26
Shrimp	USA	10	10	10	7	9	16	25	24	
	Alaska	7	8	7	4	8	13	18	19	22
Molluscs	Alaska									1

[a] Total North Pacific.

[b] Includes herring eggs on kelp.

SOURCE: Gulland, 1972.

the environment. Table 13 indicates the importance of depth in estimates of flatfish taken from the Gulf of Alaska, as well as representative fish species. Westerheim (1970) generalized that maximum catches of flatfish occurred in depths greater than 400 meters for the Gulf of Alaska, but that the greatest variety of species was found in depths of less than 300 meters.

However, the impression that fish of the Gulf of Alaska are limited to a few varieties of flatfish and salmon should not be made. Quast and Hall (1972) have reviewed Alaskan fishes in the Gulf, listing 25 fish families and over 100 species. Several species have been shown to be abundant and potentially able to support new fisheries, such as rockfish (Alverson, et al., 1964) and the pelagic pomfret (Hitz and French, 1965).

Life history and distribution data for some of the more abundant species in the Gulf of Alaska has been summarized by the Arctic Env. Inform. and Data Center (1974).

Information on fish of the Bering Sea is dominated by Bristol Bay stockeye salmon. This salmon fishery is the largest in the world. However, several other species are taken in large quantities; halibut, herring, and a number of species of demersal fish (Gulland, 1972). A very large proportion of these fish are taken by foreign fishing

TABLE 13

Pounds of Flatfish caught per hour of Exploratory trawling by Depth Intervals in the Alaska Peninsula Region (from Alverson, et al. 1964)

Species	Depth in Meters				
	1-90	90-181	182-272	273-364	365-547
Atherestes (Turbot)	26	137	541	992	698
Citharichthys (Sand dab)	T	1	T	0	0
Glyptocephales (Rex sole)	1	4	34	26	120
Hippoglossoides (Flathead sole)	21	80	145	31	2
Isopsetta (Butter sole)	6	1	T	T	0
Lepidopsetta (Rock sole)	159	46	3	0	0
Limanda (Yellowfin sole)	13	8	0	0	0
Microstomus (Dover sole)	T	1	6	29	87
Parophrys (English sole)	T	T	0	0	0
Platichthys (Starry flounder)	4	T	0	0	0
Pleuronectes (Alaska Plaice)	1	T	T	0	0
Psettichthys (Sand sole)	1	T	0	0	0

(T = Trace)

vessels. Foreign vessels harvested nearly 600,000 metric tons of fish from the Bering Sea in 1966. In 1973 the foreign catch had dropped to 100,000 metric tons.

Table 14 lists the potential yield of demersal fish stocks, (excluding the large potential shellfish resources), in the Bering Sea, as compared to the Gulf of Alaska. Assuming relative correctness of these estimates, the Bering Sea appears to be about three times more productive for these species than the Gulf of Alaska.

TABLE 14

Potential annual yields from the major demersal fish stocks (thousand metric tons). Adopted from Gulland (1972).

Species	Gulf of Alaska	Bering Sea
Yellow sole	1	180
Rock sole	15	110
Arrowtooth flounder	60	20
Flathead sole	20	20
Dover sole	10	0.5
Halibut	18	2
TOTAL	124	332
Pacific Ocean perch	50-70	14-21
Pacific hake	—	—
Alaska pollock	50	550
Pacific cod	30	40
Spiny dogfish	1	—
TOTAL	265	940

relative correctness of these estimates, the Bering Sea appears to be about three times more productive for these species than the Gulf of Alaska.

Demersal fish appear most abundant at depths less than 100 meters in the Bering Sea. Catches by commercial fishing fleets in this area indicate that most of these fish feed on the continental shelf during the summer and winter on the continental slope.

Fish of the Artic Ocean include both pelagic and demersal species. Adult pelagic species are represented by the Artic cod, Artic char, and the Pacific herring smelt. Demersal species are represented by Artic staghorn sculpin, hamecon, Bering flounder, and saffron cod (Alverson and Wilimovsky, 1966).

Arctic fish are very few in terms of species (about 69), although large populations of individual species may occur during the summer. The sparseness of fish is a function of such environmental factors as low temperatures, low primary productivity, and ice-scouring in the shallow littoral zones (Arctic Institute of North America, 1974). According to Alverson and Wilimovsky (1966), definite preferences or tolerances of these factors by Arctic fish are apparent.

Marine mammals

Marine mammals comprise a conspicuous part of Alaska's marine fauna because of their numbers and relative size. Mammals occurring in Alaskan waters are classified in three major orders: Carnivora, Pinnipedia, and Cetacea. The carnivores are represented by the sea otter and polar bear, while the pinnipeds (seals, sea lions, and walruses) are represented by nine species. Whales, porpoises, and dolphins, collectively known as cetaceans, are ddivided into two sub-orders: the odonicetes (toothed whales), and the mysticetes (baleen whales). There are at least 22 species of marine mammal species inhabiting the Gulf of Alaska region, 25 species in the Bering Sea region, and 20 species in the Arctic Ocean region. Table 15 lists the species, area found, and population estimates.

Many of the marine mammal species that occur in Alaskan waters are seasonal entrants and range in international waters. Consequently, they are of concern and potential value to many nations. The Marine Mammal Protection Act of 1972 prohibits the harvest of marine mammals except for subsistence use by certain Alaskan natives, display, and scientific collections. A further exception is the fur seal harvest which is regulated by international treaty. An estimated 76,000 individual mammals (about 15,000 metric tons) are harvested annually in the Bering Sea.

Sea otters are presently found from Yakutat Bay westward to Prince William Sound, the Kenai Peninsula, both sides of the Alaska Peninsula and Aleutian Islands, and St. George Island in the Bering Sea. Sea

Table 15

Occurrence of Marine Mammals in Alaska

Species	North Pacific	Bering Sea	Arctic Ocean	Estimated Total Population
Polar Bear	--	PR	PR	3,500
Sea Otter	PR	PR	--	125,000
Steller Sea Lion	PR	PR	R	200,000
Northern fur seal	SE	SE	R	1,200,000
Harbor seal	PR	PR	SE	100,000
Ringed seal	--	PR	PR	250,000
Harp seal	--	--	A	—
Hooded seal	--	--	A	—
Ribbon seal	--	PR	SE	90,000
Bearded seal	--	PR	PR	300,000
Pacific walrus	--	PR	PR	130,000
Gray whale	SE	SE	SE	11,000*
Fin whale	SE	SE	SE	13,000*
Sei whale	SE	SE	R	20,000*
Minke whale	PR	SE	R	—
Blue whale	SE	SE	--	—
Black Right whale	SE	SE	--	250*
Humpback whale	SE	SE	SE	1,200*
Bowhead whale	--	PR	SE	2,000*
Sperm whale	SE	SE	--	150,000*
Beluga whale	PR	PR	SE	2,000*
Killer whale	PR	SE	SE	—
Bering Sea beaked whale	SE	SE	--	—
Goose-beaked whale	SE	SE	--	—
Giant Bottlenose whale	SE	SE	--	—
Short-finned pilot whale	SE	--		—
Narwhal	--	--	R	—
Dall porpoise	PR	SE	--	—
Harbor porpoise	PR	SE	R	—
White-sided dolphin	R	--	--	—
Northern Right-Whale dolphin	R	--	--	—

R - Rare
A - Accidental
SE - Seasonal Entrant
PR - Permanent Resident

*Whale populations include entire North Pacific Ocean.

Sources: USDI, 1973; Nishiwaki, 1967; Brooks, 1971; Scheffer, 1972; Burns and Morrow, 1973; Berzin and Rovnin, 1966; A.D.F. and G., 1973.

otter habitat consists of shallow coastal waters less than 75 meters deep. Typically, they are found along rocky coasts exposed to the open ocean, especially in the vicinity of offshore rocks and extensive kelp beds.

Kenyon (1969) estimated the world population of sea otters in 1965 to be about 33,000, with Alaska accounting for about 26,500. In 1973 the Alaska Department of Fish and Game (1973) reported a maximum of about 125,000 sea otters in Alaska, 40,000 in the western Gulf, and 70,000 in the Aleutian Islands.

The diet of sea otters consists largely of echinoderms (especially sea urchins) and molluscs. Frey (1971) indicated that fish also made up a part of the diet. Food is always consumed in the water by sea otters, never on land.

Polar bears are associated with the ice edge and consequently these animals move north and south seasonally. They are found throughout the Bering Strait, and the Chukchi and Beaufort Seas. Brooks (1971) indicated that there are two distinct populations of bears in Alaska, one in the Chukchi Sea and the other in the Arctic Ocean. Brooks also estimated the number of bears in Alaska to be about 3,500 animals. The primary food items of the polar bear are the bearded and ringed seals, although other wildlife and carrion are taken at will.

Females breed once every three years. Cubs (usually one or two) are born in winter, weighing about one pound. The mother continues her association with the cubs for about 2-1/2 years before breeding again.

The pinnipeds are common inhabitants of the continental shelf. Sea lions generally prefer the more southern regions of Alaska, such as the Gulf and the Aleutian Islands, while largha, ribbon, ringed, and bearded seals prefer the northern waters of the Bering Sea and Arctic Ocean. The latter two migrate seasonally with the advance and retreat of the ice. Sea lions, harbor seals and fur seals are associated with offshore rocks and land for hauling (resting) and breeding. (One group of harbor seals bear white coated pups and inhabit the ice front.)

The northern fur seal supports a considerable commercial enterprise based on its pelt. Management is shared by several nations. Its main breeding grounds are the Pribilof Islands, where they are harvested (Baker, et al., 1970). Between 40,000 and 50,000 fur seals are taken annually, for a gross income of about 3-1/2 million dollars (Kenyon, 1971).

The Pacific walrus occurs seasonally in the Bering Sea and Arctic Ocean. They winter almost entirely in the Bering Sea. Some stay while others migrate back to the Arctic Ocean in the spring. About 130,000 walrus inhabit Alaskan waters.

Their diet consists primarily of molluscs and their location is generally determined by the location of extensive clam beds. Food sources for walrus are much more restricted than for other pinnipeds (A.D.F. and G., 1973).

The Mysticeti, or baleen whales, are those whales with baleen plates in their mouths which are used to strain plankton and other food from seawater. These whales undergo extensive migrations, often traveling to the western shores of Mexico during the winter months. This migratory nature has made these mammals vulnerable to exploitation from many nations. Consequently, stocks of the larger whales have been severaly depleted by international whaling. As the larger whales become more scarce, the smaller whales are subject to exploitation as well. Management of whale stocks depends on population parameters such as birth and death rates, and stock size. This information is difficult to obtain, as is concensus between exploiting nations regarding conservation. As a result, whale populations continue to be stressed.

There are 12 species of toothed whales inhabiting Alaskan waters. The sperm whales are the largest of the toothed whales. Their principal food item is squid. Killer whales are the most widely distributed marine mammal in the world (Nishiwaki, 1967), inhabiting all oceans in the northern and southern hemisphere. Prince William Sound is an area of concentration for killer whales, where they feed on fish, other marine mammals, and birds (Scheffer, 1972).

The beluga whale ranges throughout Alaskan waters from the Gulf to the Arctic Ocean. They enter estuaries and rivers in the summer, consuming fish, crustaceans, and squid.

The porpoises are very common in Alaskan waters, particularly in summer months. Harbor porpoises are more common inshore, while Dall porpoises are more common in offshore waters. There is no commercial exploitation of these mammals except for a very few for exhibition. Principal items in the diet are squid and fish (Mizue, et al., 1966).

(5) Coastal and Marine Birds

The avifauna of the offshore and coastal regions of Alaska is notably varied and abundant. Many of the seabirds, shorebirds, and waterfowl that breed in or migrate across offshore and coastal regions of Alaska originate from trans-Pacific or trans-equatorial regions. Thus Alaska's bird resources are a national and international resource of considerable value and concern to many nations. Seabirds and waterfowl provide food for subsistence and commerce, others provide recreational opportunities, and all are aesthetically and ecologically valuable (Bartonek and Sowl, 1972).

Birds are recognized as an important part of the marine ecosystem. Birds transfer, concentrate and recycle nutrients and energy between trophic levels, as well as within and/or between regions. Bird droppings are considered as important source of phosphates and nitrates which help support plankton production, and ultimately, regional fisheries (Aingley, 1974).

Birds that inhabit coastal and offshore waters of Alaska have been treated, in varying degrees and oceanographic ranges, in several works. Gabrielson and Lincoln (1959) summarized the early accounts of bird observations in Alaska. Sanger (1972) estimated the numbers and biomass of seabirds in the subarctic Pacific region, and King and Lensink (1971) reported on an evaluation of migrating bird habitat in Alaska.

At least 8 families, 27 genera, and 59 species of truly pelagic birds occur in the offshore waters of Alaska. This does not include the more coastal birds such as loons, grebes, several species of shorebirds, ducks, geese, and swans. The estimated total standing stock of seabirds (excluding the Arctic Ocean) is about 37.2 million (Sanger, 1972). The average densities tend to be highest in the coastal regions. Summer densities are much higher than in winter. Highest summer standing stock was found in the central Gulf of Alaska, perhaps because of its large size.

Specific areas that are of critical importance to birds in the northern Gulf area are sea cliffs that border the mainland and offshore islands, tide flats in Orca Inlet, wetlands in the Copper River Delta, and pelagic foraging areas off the Copper River Delta. Sea cliffs provide nesting and resting habitat for a variety of seabird species.

Portions of the coastline, offshore islands and waters, estuaries and river deltas in the northern Gulf provide habitat for vast numbers of birds. About 2.2 million seabirds in the coastal area during winter and 10.6 million during summer were reported by Sanger (1972). Bartonek and Sowl (1972) estimated the numbers of seabirds in the Gulf of Alaska alone at about 9 million. Nearly 150,000 black brant and 250,000 cackling Canada geese migrate directly across the Gulf of Alaska between the Alaska Peninsula and British Columbia. Nearly the entire North American breeding population of 12,000 dusky Canada geese breed in the Cooper River Delta each spring (Chapman, et al., 1969). Fall flights have ranged from 20,000 to 42,000 duskies. The delta also attracts about 10,000 snow geese in the fall (ADF & G, 1973). About 10,000 Canada geese and 10,000 snow geese inhabit the Yakutat area.

Over 100 species of birds have been observed in the Cook Inlet area. Wetlands along the periphery of the Inlet are particularly important to waterfowl during spring and fall migrations. Of the seabird colonies in Cook Inlet (about 26) the most important are the Barren Islands, where more than 500,000 birds breed.

Almost the entire world population of emperor geese (about 100,000) winter in the Aleutians and the southwest Gulf of Alaska, where they frequent coastal lagoons and bays. Hundreds of thousands of ducks and geese occur in the area, notably black brant and emperor geese. The black brant population of the Pacific Flyway is often characterized as staging entirely in Izembek Lagoon on the north side of the Alaska Peninsula and then leaving en masse.

A total of 183 species of birds have been recorded in the Aleutian Islands and adjacent waters. Fifty-four species of birds breed on the Aleutian Islands National Wildlife Refuge while 75 species are common migrants and 55 are casual or accidental species (Sekora, 1973). Estimates indicate a minimum breeding population of four million pelagic birds in the Aleutian Refuge.

Bristol Bay serves as a crossroads for waterfowl from many other countries. Large eelgrass and saltwater lagoons in Bristol Bay, as well as the numerous ponds and lakes, constitute the region's most important waterfowl habitats. They are used primarily as resting and feeding areas during migration. In spring and fall, as many as 32,000 black brant, 10,000 Canada geese, 60,000 emperor geese, 5,000 pintails and scaup, and 100,000 eiders have been observed in Chagvan and Nanvok Bays, but these are only part of a transient population that uses the area. In addition, several million sea birds nest along coastal cliffs.

More than half of the 352 species of birds recorded in Alaska have been recorded in the Seward Peninsula - Kotzebue - Selawik region (USDI, 1973b; 1973d). At least 109 are nesting migrants, about 15 are nesting residents, and about 41 probably occur as non-breeding migrants and vagrants. About 32 seabird colonies are found along the northwest Alaskan coastline. For example, seabirds resting along the rocky sea cliffs are the most conspicuous element of the avifauna in the Cape Thompson and Cape Lisburne area. Five seabird colonies in this area exceeded 420,000 breeding birds in 1960. Murres were by far the most abundant seabird species numbering almost 400,000 (USDI, 1973b).

Although the Chukchi seabird population is neither large nor concentrated, the area is an important migratory pathway in the Asiatic - Pacific flyway (Watson and Divoky, 1972). The bird fauna of the offshore waters of the Chukchi Sea is considerably richer than that of the Beaufort Sea, particularly with regards to murrelets, auklets, and puffins.

Migratory waterfowl of the Beaufort Sea travel all the continental flyways and several international flyways. The arctic coastal plain and offshore islands support an estimated spring breeding population of about 500,000 ducks, geese, and swans (Montgomery and Boughton, 1974). Sea ducks, phalaropes, and gulls are the most numerous birds in the Bering Sea. Also present in large numbers are loons, jaegers, alcids, and arctic terns. Bird distribution is generally limited to within 35 miles of shore (Bartels, 1973). Of particular importance is the migration route along the coast. The king eider migration alone has been estimated at one million birds passing Point Barrow. Two-thirds of the avifauna of the Canadian arctic islands pass along the Beaufort Sea coast.

Oldsquaw numbers on the Arctic slope reach 400,000 birds on the beach at one time. However, many more pass through the area during the summer. Almost all common eiders nest on offshore islands along the coast. Brant concentrate their nesting activity on the islands of the river deltas. The only known nesting area for snow geese in the United States is on an island of the Sagavanirktok River Delta.

Although waterfowl can be found throughout the Beaufort Sea region, the area within five miles of the coast (the barrier islands) accounts for the greatest number. These islands stop the pack ice when it drifts toward the shore and ameliorate strong winds, providing a shallow, sheltered, ice-free area for feeding, nesting, and molting. This area is obviously of critical importance to birdlife (Montgomery and Boughton, 1974).

Frame (1973) noted birds were more abundant within 50 miles of land where ice was thinner and open leads (cracks in the ice) more common. Plankton, molluscs, and small fish in the Beaufort Sea during summer provide a rich feeding ground for seabirds.

(6) Unique Environments

"Unique" environments in Alaska are considered to be those habitats critical to the existence of certain fish and wildlife populations or those areas where uniquely abundant fish and wildlife populations occur.

Isolated rocks, inlets and rocky points along the mainland and offshore islands are used by vast numbers of seals or sea lions for breeding rookeries or hauling grounds, and could be considered unique environments. There are about 200 known sea lion rookeries along the Alaskan coast. The Pribilof Islands are the only northern fur seal breeding areas in the United States; about 1.2 million fur seals congregate on the Pribilofs each spring to breed. The Walrus Islands and Amuk Island in the Bering Sea, the only American walrus hauling grounds, are also unique.

Sea ice isa unique environment, as many marine mammals depend on this habitat. Furthermore, ice plays an important role in arctic primary production.

All existing and proposed Alaskan coastal wildlife refuges should be considered unique environment.

Alaska's Gulf coast region, Aleutian Islands, offshore islands and mainland promontories of the Bering Sea provide resting and nesting habitat for a vast number and variety of seabird species; therefore, the approximately 250 seabird colonies in Alaska, supporting several million seabirds, are considered unique environments. Buldir Island in the western Aleutian Islands should be considered unique, as the entire world's population (200 to 300) of the endangered Aleutian Canada goose breeds here. Izembek Lagoon, located on the north side of the Alaska Peninsula, is the staging area for the entire world's population of black brant (150,000), cackling geese (150,000), and emperor geese. Izembek Lagoon also contains the largest known eelgrass beds in the world.

Nearly the entire population of emperor and cackling geese and half the continental population of black brant nest in a narrow zone of coastal habitat in the Yukon Delta. The entire Pacific Flyway populations of white-fronted geese and most of the Pacific Flyway whistling swans also nest on the Yukon-Delta. The entire North American breeding population of about 12,000 dusky Canada geese breeds only in the Copper River Delta area adjacent to the northern Gulf of Alaska.

Approaches (bays) to all anadromous fish streams should be considered unique environments. Waters adjacent to fresh-water streams provide subsistence and protection to young anadromous fish as they adjust to the marine environment. This transition period from fresh to salt water is one of the most critical periods in the life of young anadromous fish.

Many coastal areas, particularly in the Central Gulf of Alaska, are shellfish spawning grounds. Larval shellfish (king and Tanner crabs) utilize the rich surface waters during their several-month planktonic life stage.

e. Natural Phenomena Unique to Area with Potential to Cause or Contribute to Environmental Impacts of Proposed Action

A wide range of environmental and geologic problems may be experienced in Alaska. Phenomena of major importance in the southern portions of the state are earthquake activity, potential fault offset, volcanic activity, seismic sea waves, surges, mountainous terrain, high waves and strong winds. In the northern portions of the State, problems regarding sea ice movement and permafrost predominate. Geologic phenomena have been discussed in the Geology section, while winds and wave have been discussed under Climate and Physical Oceanography, respectively. Seismic sea waves (tsunamis) have been discussed in the Physical Oceanography section for the Pacific region.

Ice of all types can cause or contribute to environmental impacts throughout Alaskan waters, but impacts are generally north of the Aleutian Islands which act as a barrier to southern extensions of winter ice cover. Ice can form on fixed structures and ship's superstructures, thus increasing the mechanical stresses. Ice propelled by tidal currents can also present a potential hazard to fixed structures due to collisons. A similar hazard is present when icebergs or bits occur in navigation routes. Such conditions may occur in Cook Inlet, Bristol Bay and all waters to the north, as well as nearshore areas from Prince William Sound to Juneau.

Pack ice in all waters north of the Aleutian Islands poses a hazard to fixed structures because the ice cover moves great distances. Once in motion the ice has tremendous force. When it encounters the coastline, ice blocks are thrust up on the beach, scouring and gouging the beach and adjacent sea bottom. This action has been reported to occur in depths of 90 to 150 feet on the outer continental shelf. Scour widths of 100 to 200 feet, lengths of 2 to 3 miles, and scour relief of 30 feet have also been noted (A.I. of N.A., 1974).

Glaciers, another form of ice, have been known to surge, or advance rapidly (Swift, et al., 1974). The cause of glacier surges are unknown and therefore are unpredictable in time.

Another natural phenomenan which may cause environmental impact is severe seasonal flooding. The hazard is greatest in southeastern Alaska where mountains with huge snow fields and glaciers skirt the Gulf of Alaska. Post and Mayo (1971) discuss the floods caused when water is released from ice-dammed lakes and rivers.

B. Description of Nearshore and Coastal Zone Environment

1. Atlantic Region (and Sub-Areas)

a. Geology

The geology of the nearshore and coastal zone has been described previously in the discussion of the offshore environment (section II A 1 a) since unlike biological and some other physical parameters, geologic structures are not commonly distinguished according to an arbitrary division based on water depth or proximity to the shoreline. Where specific geologic structures are unique to a nearshore area, they are noted as such.

b. Biological Environment and Communities of the Coastal Zone

The Atlantic coastline extends 5,565 miles and can be divided into three distinct physiographic regions. The area from the Florida Keys to the Cape Fear River in North Carolina can best be categorized as a smooth coastline, occasionally indented with estuaries and embayments; with a series of barrier islands. These barrier islands are sandy dunes which are constantly moving landward. Estuarine ponds or sounds are common between these islands and the mainland. The most prominent barrier island system occurs off the mainland of North Carolina. The "Outer Banks" extend from just north of the Cape Fear River to the Virginia-North Carolina Border. The Pamlico and Albemarle Sound system comprise the largest estuarine lagoon along the Atlantic Coast.

Cape Hatteras marks the southern boundary of the second physiographic zone, the Mid-Atlantic bight. This section is characterized by large indentations (embayments, estuaries, and ponds) and extends northward to Cape Cod. The majority of these estuaries result from drowned river valleys, but the Long Island Sound was enclosed by large coastal structures which have been covered by glacial deposits. Other emergent structures of similar origin include Cape Cod, Martha's Vineyard, Long Island, Block Island and Nantucket Island. The well known bays in this area include the Chesapeake, Delaware, and Narragansett Bays. The third coastal province includes the irregular coastline north of Cape Cod and is characterized by exposed rocky headlands and unconsolidated beaches.

The description of nearshore and onshore biology is categorized and discussed briefly by community type (see Table for representative flora and fauna). The discussion of community types is limited to those which might be affected by OCS development. Additional and complementary discussion is given for similar community in the Gulf of Mexico (Section II.B.2.b.).

(1) Benthic Algae

Benthic algae, including diatoms and macrophytes figure prominantly in the energy flow of the nearshore community throughout the area. Artificial hard substrates such as pilings and rocky structures as well as silty and sandy substrates are colonized by these benthic algae. Pomeroy (1959, in VIMS, 1974) estimated that the productivity of these flora in a Georgia marsh average 180-200

Table 16 Representative flora and fauna of Atlantic Coastal Zone Communities (see also text).

(1) Benthic algae

a. Benthic
Porphyra, *Enteromopha*, *Ulva*, *Calothrix*, *Chaetermorpha*
Pocockella, *Laminaria*, *Ascophyllum*.

b. Intertidal
Calothrix, *Entrophysalis*, *Plectonema*, *Ulva*, *Porphyra*,
Enteromophos, *Fucus*, *Cladophora*, *Codium*, *Bryopsis*,
Sargassum.

(2) Submerged seagrasses

Eel grass (*Zostera*), *Halodule*, Turtle grass (*Thalassia*), Manatee grass (*Syringodium*), Widgeon grass (*Ruppia*), *Potamogetan*.

(3) Mangrove swamp systems

a. Flora
Mangroves (*Rhizophora*, *Avicennia*, *Laguncularia*)

b. Fauna
Crabs, barnacles, oysters, snails, turtles, crocodiles, bears, wildcats, pumas, rats, fish, birds.

(4) Rocky sea fronts

Algae, mussels, limpets, chitons, urchins, starfish, lobsters, crabs, barnacles, oysters, periwinkles.

(5) High energy beaches

Birds, fish, beetles, copepods, amphipods, bivalves, snails, mole crab (*Emerita*).

Table 16 (Cont.)

(6) Barrier beaches

Sea oat (Uniola), cordgrass (Spartina), Amophila, Juncus, myrtle trees (Baccharis, myrica), oak trees, pine trees.

(7) Salt marshes

Spartina, Salicornia, Distichlis, Juncus.

(8) The oyster-mussel reef

Oysters (Crassostera), mussels (Mytilus), algae, hydroids, barnacles, polychaetes, boring sponges, molluscs, worms.

(9) Worm and clam flats

Soft-shell clam (Mya), scallop (Placopecten), lobster (Homarus), crab (Cancer)

(10) Salt pond

Eel grass (Zostera), Spartina, diatoms (Nannochloris, Stichococcus), clams, oysters, mussels.

(11) Plankton-based pelagic-estuarine system

Diatoms, dinoflagellates, zooplankton (Acartia sp., Eurytemora, Nemysis, Oithona), herring, anchovies, smelt, minnows, weakfish, striped bass, birds.

g C/m^2/yr. for the diatoms and as high as 320 g C/m^2/yr. for non-diatomaceous species. A total of 239 species of macrophytes have been identified in the State of North Carolina alone (VIMS, 1974). Grazing, relative exposure, light levels and availability of suitable substrate are significant factors in the occurrence and population levels of benthic macrophates. Humm (1969) hypthesized that all oceanic algae along the Atlantic coastline have resulted from two geographic populations, one of tropical origin with its north boundary at Cape Canaveral, the other originating in the northwest Atlantic with Cape Cod as its southern boundary. The resultant algae populations in the Central Atlantic region are comprised of eurythermal (capable of tolerating a wide range of temperature) species of both regions.

No natural intertidal rock has been identified in the Central Atlantic region. Artifically placed hard substrates and naturally occurring sounds, inlets, beaches, offshore reefs, and muddy beaches offer suitable habitat for benthic algae.

Nantucket Shoals-Cape Cod represents a sharp boundary of benthic algae organisms. The cold waters of the Labrador Current are found north of this boundary, and warmer waters with partial origins from the Gulf Stream prevail to the south. There is overlap with several more eurythermal species found occasionally on either side.

(2) Submerged Seagrasses

Seagrasses form an important part of the benthic community wherever they occur. They serve as: 1) necessary hard substrate for benthic organisms, 2) major food sources, 3) shelter for organisms and occasionally abate high wave energy, 4) provide detrital food for estuarine and nearshore organisms, 5) stabilize and aid in bottom deposition by abating bottom currents (VIMS, 1974).

(3) Mangrove Swamp Systems

Mangrove swamps comprise an important shoreline community south of Cape Canaveral. The Cape marks its northern boundary with few isolated mangrove beaches occurring to the north. One continuous beach stand of mangroves covers approximately 675 square miles in south Florida. The predominant physical factor which limits the northern spread of the mangrove is temperature. Hard frosts are invariably fatal. Regular tidal flooding is also necessary to maintain the mangrove forest stands.

Mangrove swamps are valuable in their ability to abate and absorb wave energy during storms and hurricanes. This aspect is particularly important during hurricanes when the sea level is elevated due to storm surge. Menhaden, mullet, spotted sea trout, snook, tarpon, red drum, pink shrimp and other species utilize these swamps as nursery grounds. Oysters commonly occur in marketable quantities in these areas. Eighty-nine species of aquatic birds, as well as manatees, otters, crocodiles and alligators can be found in these swamps. Normal cutting, dredging, and filling have been responsible for the loss of much of the mangrove community's original area.

(4) Rocky Sea Fronts

The primary physical factors which govern biotic zonation in this type of habitat are; availability of rocky substrate, intermittent exposure o air, and breaking waves. The flowing sea water enriches the environment by washing in nutrients and oxygen and carrying out metabolic waste. The naturally occurring rocky beach is restricted to the North Atlantic region where large tidal fluctuations (6 meters or more) commonly occur.

(5) High Energy Beaches

This type of habitat is characterized by sandy and sand-gravel substrates, and breaking waves. High energy sandy beaches comprise most of the Atlantic coastline south of Cape Cod. The surface configuration of high energy sandy beaches may be altered by the erosion of storm waves, changing the substrate type as well as the beach topography. Storm induced erosion may alter the biotic community along a specific area for a period of months to years.

(6) Barrier Beaches

Barrier beaches, as has been described in a previous chapter, extend over the majority of the Atlantic coastline south of Cape Cod. These beaches normally are made up of sandy substrate and possess sand dunes and marshes. Salt marshes normally occur behind a series of dunes, and border on salt water lagoons which separate the beaches from the mainland. The beach and dune system receives sand from wave transport on the seaward edge and is continually moving landward. This progression results in a succession of habitat types behind the dunes.

Man has attempted to stabilize these dunes with snowfences and artificial plantings of dune grasses. These efforts have resulted in the erosion of the beach and ultimate erosion of the foredune system (normally a continuous dune closest to the surf zone). This stabilization has resulted in typical dune communities. The incidence of wind-borne salt spray primarily limits the areal coverage of this type of community. This zone is well above the height reached by sea water under normal or severe storm conditions. Storm generated waves have breached the barrier island system repeatedly, causing wave overwash across the islands into the marshes behind them. This phenomenon results in disruption of the normal community and may require several years for significant recolonization.

The above description holds for the entire Atlantic coastline where barrier beaches occur.

Barrier beaches supply extensive food sources and breeding areas for many shore and sea birds. The Atlantic Flyway, one of the major waterfowl migratory routes, runs along these Atlantic beaches. Seasonal populations of these waterfowl can reach as high as hundreds of birds per acre.

(7) Salt Marshes

The salt marsh type of habitat occurs on unconsolidated sediment which is regularly flooded by tidal action. Normally, deep channels are maintained throughout the marsh by tidal currents. The primary factor governing vegetation distribution is elevation.

Silt is constantly trapped due to slowing of current, and plant detritus is exported on the ebb tide. This detritus forms an important food source throughout the estuarine portion of embayments and along the coastline. Salt marshes exhibit productivity on the same order as fertile cultivated land systems. Major natural stresses in the marsh system are due to variations in salinity, temperature, and dissolved oxygen. Salinities vary annually from 1-28°/oo and temperatures can show a 10°C. daily variation, and an annual variation from -0.5°C. to 30.5°C. Ice scour and summer desication have caused mass mortalities in the North Atlantic Region (TRIGOM, 1974).

Man is constantly altering the salt marshes, with dredging, filling, spraying with pesticides, and dumping. The salt marsh community receives agricultural runoff. These effluents are heavy in pesticides and nutrients from fertilizers and animal wastes. Animals within the salt marsh food web have shown the capability of concentrating these pesticides to stressful levels (TRIGOM, 1974).

Repeated exposure to oil may have lethal results on Spartina, as was shown by a Bunker C spill in Chedabucto Bay, Nova Scotia. Heavy initial oiling, and repeated leaching caused extensive mass mortalities. Residence time for the oil in sediments was predicted to exceed 3 years with recovery requiring more time (Council on Environmental Quality, 1974).

Many fish utilize the marshes as breeding and nursery grounds. A listing of the more common such organisms is given in the Active Swimmers-Nekton section.

(8) The Oyster-Mussel Reef

Aggregations of oysters Crassostrea virginica and mussels Mytilus edulis are typical of the Atlantic coast. Oysters are rare north of Cape Cod, however. Oysters appear to show marked preference for the setting of their larvae upon their own shell, which leads to the formation of large aggregates. This reef building may cause extensive alterations of local currents, substrates, and deposition of pseudofeces (indigestible particles filtered from the water). The surfaces of the oyster and mussel shells offer clean hard substrates to epibenthic organisms which would not be present if only unconsolidated substrate were available.

Salinity, temperature, and desiccation are the primary physical factors which govern distribution of these communities. Mussels and oysters filter plankton and detritus from the water. This type of community is presently stressed by a disease (MSX as described in Andrews, 1966) which has caused mass mortalities along the coast. Further, a significant number of these areas have been closed to commercial fishing because these organisms concentrate bacteria, present in human sewage outfalls, to health hazard levels. Because these organisms are sessile (they cannot move across the bottom) and are filter feeders, they are susceptible to high turbidity caused in part by dredging and filling. Large transplanting programs are underway to establish reefs in areas where they have naturally occurred in the past. Their success coupled with a gradual increase in resistance to the widespread disease described above have yielded slowly increasing catches in the last several years. Pesticides, hydrocarbons, and heavy metals all can be concentrated by the oyster.

(9) Worm and Clam Flats

Large expanses of intertidal and subtidal mud flats extend along the Atlantic coastline. Temperature, salinity, tidal flushing, degree of exposure during the normal tidal cycle, and substrate all influence the distribution of this type of community. The number of species occurring in this type of community is often quite large due to the availability of high levels of nutrients borne by tidal waters and land-runoff. The numbers of benthic organisms may be as high as 355,000 per square meter (Odum, et. al., 1974). The preferred habitat for this type of community is a low energy, unconsolidated sediment between intertidal elevation and 20 meters water depth. These communities are most productive where active deposition of both silt and organic detritus occur, and where protection against active surf is provided by headlands, spits or barrier beaches. Plankton are the main primary producers in this community type. These communities are actively fished, resulting in an annual commercial fisheries value of $2,900 to $3,750 per acres; indirect economic benefits of phytoplankton and macrophyte production, and spawning habitat, may exceed these values. The major natural stresses affecting this type of community include severe temperature and salinity fluctuations and shifting sediments due to abnormal weather or sea conditions.

(10) Salt Ponds

Salt ponds are small shallow embayments separated from the sea by barrier beaches. These ponds most commonly occur in the North Atlantic region. Limited connection with coastal waters is normally maintained by an inlet. Salt ponds are generally shallow and light penetrates to the bottom allowing high primary productivity. Nutrient input occurs from freshwater runoff, ground seepage, river outflow, and salt water moving through the inlet. These ponds are heavily used by migrating birds, and as nesting areas for many resident shorebirds and ducks.

Circulation within these ponds is sluggish and thus flushing time may be considerable. Eel grass _Zostera marina_ usually is the dominant macrophyte in these ponds. Detritus from _Spartina_ also constitutes a major food source for this type of community. Estimates of organic carbon produced in these salt ponds indicate a high productivity (263-275 grams carbon per square meter per year) (TRIGOM, 1974).

Major natural stresses which affect salt ponds include variations in salinity and temperature, scouring by winter ice, shifting of sediments, and closing of inlets by longshore sediment transport.

Salt ponds are particularly susceptible to man-induced pollution because of their proximity to heavily populated areas, their slow flushing times, and their ability to trap nutrients and pollutants. They receive marine-borne pollutants from tidal interchange, and from agricultural pollutants and sewage from freshwater runoff. One pond type community that has received heavy loads of sewage effluent is Moriches Bay on the south shore of Long Island. A commercial oyster fishery was well established in Moriches Bay prior to heavy sewage loading. The high nutrient levels due to the effluent favored the algae domination by two diatoms Nannochloris and Stichococcus which are unsuitable for oyster food. The change in dominant plankton and the high BOD (Biological Oxygen Demand) due to the sewage effluent have resulted in the virtual destruction of oyster beds in Moriches Bay. Dredging of the pond inlets also significantly affects population levels and distribution primarily by altering the salinity regime and flushing time. Clams, oysters, and mussels are the primary commercial species associated with this community types.

(11) Plankton Based Pelagic-Estuarine System

An estuary is defined as a semi-enclosed body of water in which seawater is measurably diluted by freshwater.. The estuarine environment is generally described by its salinity content (0.5%-30.0%) which may vary because of seasonal conditions or short term weather anomalies (heavy rains, droughts, etc.). Estuaries are rich in nutrients borne principally by the freshwater input and exhibit high primary and secondary productivity. The estuary also supports a high diversity of animals. Freshwater biota, oceanic biota, and biota peculiar to the mixing region of intermediate salinities occur in the estuarine habitat.

The major taxonomic groups of organisms which commonly comprise this type of community include phytoplankton, zooplankton, fishes, birds, and mammals. Temperatures may vary widely within a given estuary during normal seasonal changes. Short term anomalies in temperature are common as a result of storm activity. Nutrients and pollutants are introduced into the estuary by river runnoff and intrusions of saline waters from the marine environment. Nutrients are normally utilized rapidly by the large populations of organisms occurring in the estuary. Normally, spring and late fall plankton blooms occur. Intense zooplankton grazing during the summer contributes to the relatively high productivity commonly found. The upper, less saline portions of many of the estuaries in the Atlantic regions are used as breeding and nursery grounds by commercially important anadromous (fish which swim from the ocean into fresh or nearly fresh water to breed) species. A listing of these organisms appears in the Active Swimmers - Nekton section. Natural stresses in these habitats include large scale variations in temperature and salinities, and high turbidities. Most species normally occurring in this type of community are motile (with the exception of plankton) and can avoid stressful circumstances.

Plankton undergo the same seasonal changes in dominance as was described in the sections on offshore plankton.

Man-induced stresses on this habitat type include introduction of untreated sewage, hydrocarbons associated with agriculture (primarily pesticides), high silt levels resulting from dredging activities, oil and its derivatives, and thermal loadings. Sewage effluent adds nutrients to the water, accentuating natural plankton and macrophyte growth levels. This growth utilizes oxygen, eventually causing low dissolved oxygen levels which are stressful if not fatal to most estuarine organisms. Heavy metals have been added to estuaries for a period of years primarily from industrial wastes. These metals are primarily incorporated in sediment, and resuspension of these sediments by dredging may result in localized stresses on susceptible organisms. Long lived pesticides have been deleterious to estuarine waters. DDT, for instance, has been incorporated in sediments in serious quantities (TRIGOM, 1974). The effects of oil on the biota of a northern temperate estuary (Chedabucto Bay) have been described. Thus, the estuaries of the Atlantic coast are presently under varying degrees of man-induced stress.

c. Resources of the Coastal Zone

(1) Land Characteristics

North and Mid-Atlantic Region

The North and Mid-Atlantic region extends from the St. John River Basin in Northern Maine to the James River Basin in Southern Virginia. The region has been divided into 12 hydrologically defined areas (see Figure 63), as adapted from the North Atlantic Regional Water Resources Study prepared by the North Atlantic Regional Water Resources Study Group for the U.S. Army Corps of Engineers' North Atlantic Regional Water Resources Study Coordinating Committee[1] and from the University of Rhode Island's Coastal and Offshore Environmental Inventory--Cape Hatteras to Nantucket Shoals (URI), which uses the NAR study for its discussion of coastal zone utilization. The National Shoreline Study--Regional Inventory Report--North Atlantic Region, prepared by the U.S. Army

---

[1] U.S. Army Corps of Engineers, North Atlantic Division, 1972.

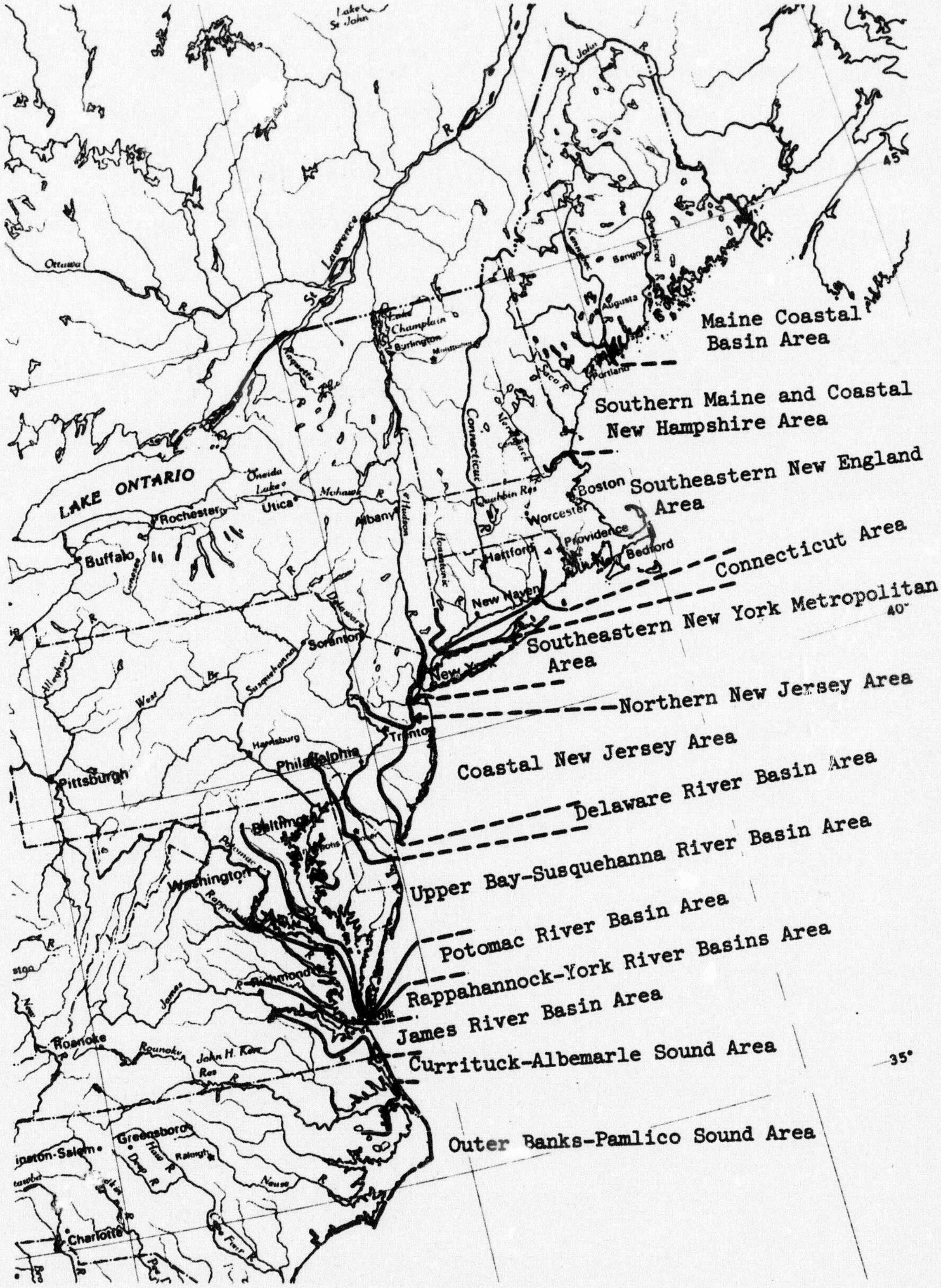

Maine Coastal Basin Area
Southern Maine and Coastal New Hampshire Area
Southeastern New England Area
Connecticut Area
Southeastern New York Metropolitan Area
Northern New Jersey Area
Coastal New Jersey Area
Delaware River Basin Area
Upper Bay-Susquehanna River Basin Area
Potomac River Basin Area
Rappahannock-York River Basins Area
James River Basin Area
Currituck-Albemarle Sound Area
Outer Banks-Pamlico Sound Area
45
40°
35°
LAKE ONTARIO
Lake St John
Ottawa
St. Lawrence
Lake Champlain
Burlington
Bangor
Augusta
Portland
Connecticut
Boston
Worcester
Providence
New Bedford
Hartford
New Haven
New York
Oneida Lake
Utica
Mohawk
Albany
Hudson
Rochester
Buffalo
Scranton
Susquehanna
West Br
Allegheny
Pittsburgh
Harrisburg
Trenton
Philadelphia
Baltimore
Annapolis
Washington
Potomac
Rappahannock
Richmond
James
Norfolk
Roanoke
John H. Kerr Res
Greensboro
Winston-Salem
Raleigh
Neuse
Charlotte
Cape Fear R

Figure 63 Areas in the North and Mid-Atlantic Region

Corps of Engineers (1971) presents data on shoreline ownership and use.

The Maine Coastal Basin, which extends from Calais on the north to the mouth of the Androscoggin River on the south, is characterized by a rugged, rocky shoreline with many deep, narrow inlets and coastal islands. Of the approximately 1900 miles of exposed shoreline in this area only about 10 miles are beaches (see Table 17).

The Southern Maine and Coastal New Hampshire area extends from the mouth of the Androscoggin River in Maine, southwest to the New Hampshire-Massachusetts border. This area contains a variety of physical characteristics, ranging from rugged rocky shoreline to sandy beaches and marsh areas. Of the 640 miles of shore in this area, about 75 miles are beaches.

The section northeast of Portland, Maine, along Casco Bay, has deep rock embayments and is similar to the rockbound shoreline of "down east" Maine. While it does have at least 50 percent rocky outcrops, it is the transition zone from the rocky shore to the sand beach shore. South of Portland the sandy beach and marsh regimes are predominant. There are a number of substantial crescent-shaped beaches which have good quality sand, suitable for beach recreation.

Table 17. Beach Shoreline in the Atlantic Coast Region (in Miles)

Area	Beach	Total Shoreline	Percent Beach
Maine Coastal Basin	10	1,900	0.5
Southern Maine and Coastal New Hampshire	75	640	11.7
Southeastern New England	1,125	1,540	73.1
Connecticut	145	270	53.7
Southeastern New York Metropolitan	331	638	51.9
Northern New Jersey	33	85	38.8
Coastal New Jersey	178	384	46.4
Delaware River Basin	75	167	44.9
Chesapeake Bay Area	378	3,076	12.3
TOTAL-North and Mid-Atlantic Region	2,350	8,700	27.0
Currituck-Albermarle Sound	278	709	39.2
Outer Banks-Pamlico Sound	640	2,282	28.0
Onslow-Pender County	205	293	70.0
Cape Fear	146	377	38.7
Myrtle Beach	69	709	9.7
Charleston	80	1,288	6.2
Beaufort-Lower South Carolina	47	1,066	4.4
Savannah-Northern Georgia Coastal	27	55	49.1
Southern Georgia Coastal	74	149	49.7
Northern Florida Atlantic Coast	75	970	7.7
Cape Canaveral	139	549	25.3
Southern Florida Atlantic Coast	185	925	20.0
TOTAL-South Atlantic Region	1,965	9,372	21.0

The New Hampshire shoreline is characterized by extensive barrier beaches in front of tidal marshes in the south and rock ledges with pocket beaches in the north. This area includes the shore of Great and Little Bays and the navigable parts of the rivers that flow into the bays (none of which are navigable much beyond 8 miles inland).

The Southeastern New England area includes the entire Massachusetts and Rhode Island coastal areas and the nearby islands, including Nantucket, Martha's Vineyard and the Elizabeth Islands. The "mainland" shoreline north of Cape Cod to the New Hampshire border is irregular with many indentations. Cliffs and bluffs are interspersed with sections of dunes. Beyond the Boston Harbor area, the shoreline becomes rockier still, until beyond the Cape Ann areas, barrier beaches fronting large tidal marshes are again characteristic. The coastline westward from Buzzards Bay to the Rhode Island line is a mixture of barrier beaches, deep indentations, low rocky headlands, marshes and ponds. Sandy beaches predominate the Cape Cod Peninsula, varying from relatively narrow barrier beaches along the southern portion to extensive dune formations along the outer sections of the lower Cape. (For a generalized portrayal of the coastal landforms of this region and the entire United States, see the National Atlas of the United States "Coastal Landforms" Map, Scale 1:7,500,000 pp. 78-79 (1967).) The Rhode Island shoreline, which includes Block Island and the Narragansett Bay area, is about 340 miles in length and the Narragansett Bay accounts for 150 miles of this length. The coastline fronting directly on the Atlantic Ocean contains a considerable portion of sandy beach.

The Connecticut area has an irregular coastline with many bays, coves and promontories. Several small offshore islands dot its central and western portions. Of the approximately 270 miles of shoreline, about 145 miles are beaches located primarily east of Norwalk Harbor.

The Southeastern New York Metropolitan area contains the Long Island coastlines and the coastal reaches of the Hudson estuary (New York City and Westchester County). The Nassau-Suffolk area is a 1,200-square mile, 20 mile wide peninsula extending 100 miles to the east. It has an exposed Atlantic-oriented flank on the south and a semi-protected Sound-oriented flank on the north. Its total coastline is over 500 miles long. The Westchester County coast and the western half of the Long Island coast are very irregular, with numerous deep bays and promontories. Eastward the coast becomes regular with very few indentations. Along the entire North Shore, beaches are generally narrow and rocky or pebbly, and usually front high bluffs or small marshes. Except at the heads of embayments, large wetlands are uncommon. Along the Sound, beaches make up 8 of the 42 miles of the coast in Westchester County, 5 of the 18 in Nassau County and 75 of the 87 in Suffolk County.

The East Shore, with 168 miles of shoreline between Orient and Montauk Points, is almost all beach, much of which is gravelly and very narrow. The beach areas front low bluffs on the north fork and glacial headlands up to 240 feet high on the south fork. Wetlands are common, particularly along the westernmost part of this area. The South Shore, with 108 miles of shoreline, consists of long, wide sandy barrier beaches facing a strong Atlantic surf. Behind these barrier beaches, for almost the entire South Shore, are long, narrow quiet backbays.

On the Hudson estuary the steep cliffs of the Palisades across from upper Manhattan mark a transition into the busy urban atmosphere of New York Harbor. Much of the 290 miles of shoreline are lined with piers, wharfs and docks along the Harbor's bays and rivers.

The Northern New Jersey area includes the basins of northeastern New Jersey beginning with the shore of the Hudson River and including the Hackensack, Passaic and Raritan River basins, Newark Bay and the New Jersey portions of the channel around Staten Island. The area is characterized by low, flat topography and extensive tidal marshes.

The Coastal New Jersey area includes the shore of Raritan Bay between the Raritan River and Sandy Hook, and the ocean shore from Sandy Hook to Cape May. The 20 miles of shorefront on Raritan Bay is characterized by high bluffs and marshlands fronted by narrow beaches. Most of these beaches are on long, sandy barrier islands. Behind the beaches are backbays, salt marshes and meadows that extend several miles inland in some places. The shores of the backbays are largely wetlands, however, there are more beaches here than along other backbay areas within the North Atlantic region.

The coastline of the Delaware River Basin consists of the Delaware Bay and the Delaware River to the head of the tidewater at Trenton. From Philadelphia south to Penns Grove the waterfront is highly developed on both banks. The 85 miles of shoreline along Delaware Bay from Penns Grove to Cape May on the New Jersey side consists of about 50 miles of wetlands and 35 miles of narrow sand beach fronting marshes. The 82 miles of the Bay shoreline from Wilmington to Cape Henlopen, Delaware, consists almost entirely of marshes in the north and of a narrow strip of sand beach fronting more marshes in the south.

The Chesapeake Bay area consists of the Chesapeake Estuary with its many tributaries and the coastal zones of Delaware, Maryland and Virginia which front on the Atlantic Ocean. The Chesapeake Bay area is divided into sub-regions based on its major tributaries: the Susquehanna, Potomac, Rappahannock-York and James Rivers. The remaining portion of this area, that fronting on the Atlantic Ocean, has sharply different physical characteristics than the Chesapeake Bay Estuary.

The Atlantic coastal portion of this area, located on the Delmarva Peninsula and from Cape Henry, Virginia south to the North Carolina line, is all sandy beach, totalling 145 miles. Of the 120 miles on the Delmarva Peninsula, the shoreline in Delaware and Maryland takes the form of long, low narrow barrier beaches fronting a series of embayments with infrequent narrow inlets connecting them to the ocean. The Virginia portion on the peninsula is less uniform. It varies from north to south from barrier island, mainland, small buffer islands, mainland and barrier beach.

South Atlantic Region

The South Atlantic coastal region as discussed here is the area from North Carolina to the tip of Florida at Key West. The region has been divided into 12 areas (see Figure 64), as adapted from information provided the Bureau of Land Management by Planners Incorporated, Washington, D.C., and from the National Shoreline Study--Regional Inventory Report--South Atlantic-Gulf Region, prepared by the U.S. Army Corps of Engineers (1971).

The region is generally characterized by a series of concave shorelines between cuspates or points such as Cape Hatteras, Cape Lookout, Cape Fear, Cape Romain and Cape Canaveral. The predominance of barrier islands is another characteristic of the South Atlantic coastal

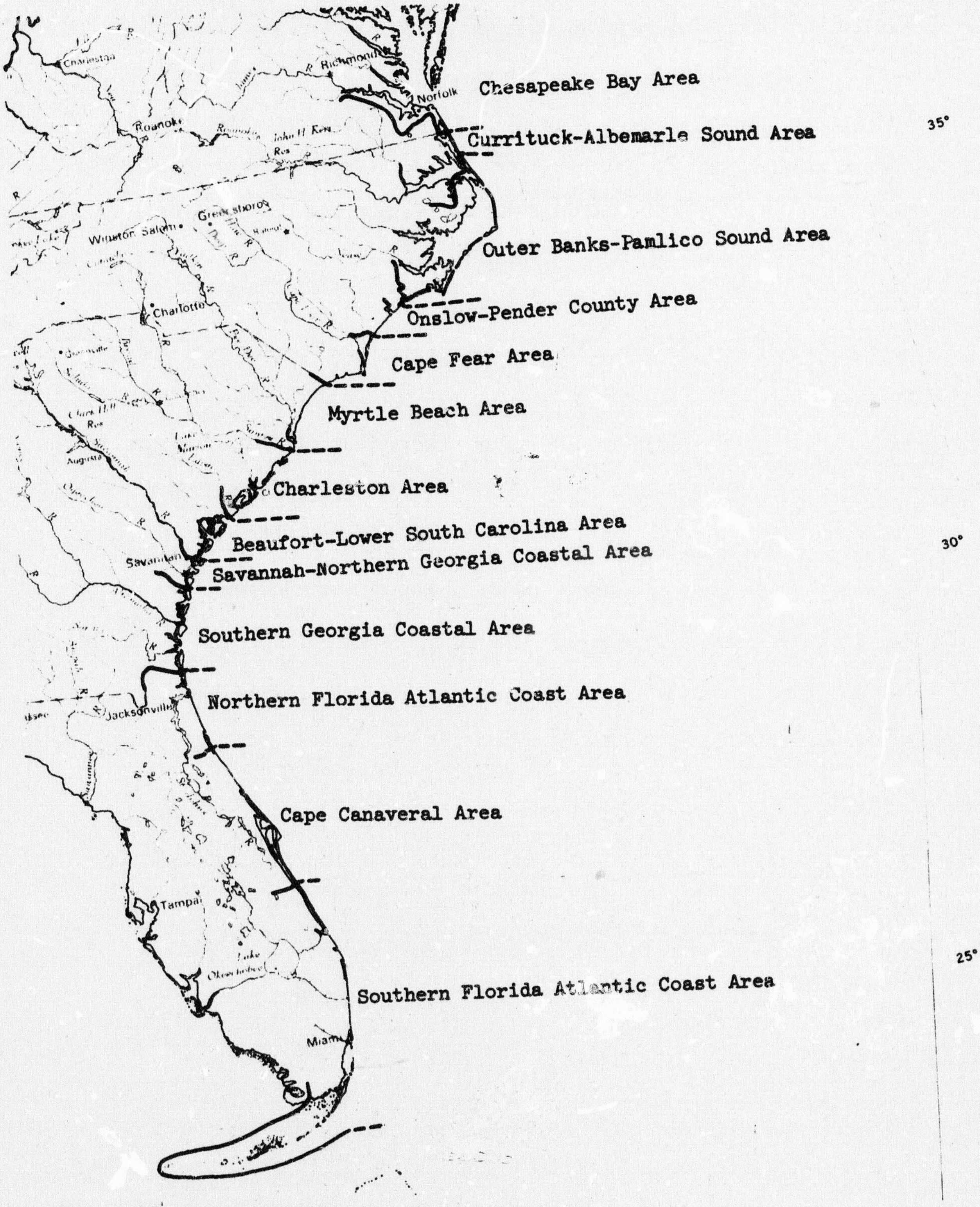

Chesapeake Bay Area
Currituck-Albemarle Sound Area
35°
Outer Banks-Pamlico Sound Area
Onslow-Pender County Area
Cape Fear Area
Myrtle Beach Area
Charleston Area
Beaufort-Lower South Carolina Area
30°
Savannah-Northern Georgia Coastal Area
Southern Georgia Coastal Area
Northern Florida Atlantic Coast Area
Cape Canaveral Area
25°
Southern Florida Atlantic Coast Area
Richmond
Norfolk
Charleston
Roanoke
Winston Salem
Greensboro
Charlotte
Augusta
Savannah
Jacksonville
Tampa
Lake Okeechobee
Miami

Figure 64 Areas in the South Atlantic Region

region. Barrier islands, which protect almost the entire Atlantic mainland in this region, vary considerably in size, shape, length, width, height and stage of development. They are usually backed by shallow, narrow lagoons, bays or sounds, usually with extensive salt marshes. The exceptions to this characteristic are the Outer Banks area of North Carolina that are separated from the mainland by the large Pamlico and Albemarle Sounds. The region includes nine major rivers, many smaller streams, lakes and ponds, forests and vast marshes, salt water estuaries, protected bays, sounds and other waterways, harbors, the ocean, and a plentiful supply of ground water. The ocean shoreline within the region is 1,192 miles in length, backed by 8,052 miles of bay/estuary shoreline. Each of these two shoreline areas has approximately 980 miles of beach.

The Currituck-Albemarle Sound area is the northernmost coastal portion of North Carolina from the Virginia line to Kitty Hawk. The area has only 23 miles of ocean front barrier beach, however, the other 686 miles of shoreline consist of marshy bay/estuary zones.

The Outer Banks-Pamlico Sound area consists of the area surrounding the vast Pamlico Sound and the smaller Core and Bogue Sounds. Barrier islands form the Outer Banks which enclose these sound areas. The counties north of Carteret are unique in that the barrier islands are separated by an expanse of water, the Pamlico Sound, which is as much as 30 miles wide at some points. Of the total, 2,282 miles of coastline of this area, 187 miles face the ocean on the barrier islands, all of which is sandy beach. The remaining 2,097 miles are estuary/bay coastline which contain about 455 miles of beach, the rest consisting generally of marsh land.

The Onslow-Pender County, North Carolina area includes the estuaries of the New and White Oak Rivers and extends from Bogue Inlet southwestward to Rich Inlet. The barrier islands along the coastline of these two counties are low lying and narrow. The coastline of the barrier islands is about 44 miles in length and is all permanent sandy beach. The 249 miles of bay/estuary coastline within the area contains approximately 160 miles of beach, the remaining portion for the most part consisting of marshes.

The Cape Fear area includes the barrier islands along New Hanover County to the north and along Brunswick County to the west, to the South Carolina line. The total ocean shoreline in this area of 68 miles is all sandy beach. Beaches exist on about 78 miles of the bay/estuary zone, with the remaining 231 miles consisting generally of marsh, vertical banks or protective structures.

The Myrtle Beach area includes the coastal areas of Horry and Georgetown Counties, South Carolina. The area extends southward from the Little River Inlet at the North Carolina line to the Santee River estuary and covers the Long Bay and Winyah Bay reaches in between. The crescent-shaped shoreline of this area is conspicuous because it lacks the barrier islands so prevalent along other areas of the South Atlantic region. Of the total 709 mile shoreline within this area, the ocean beach is 69 miles; the remaining 640 miles consists almost all of marsh.

The Charleston area includes the coastal areas of Berkeley and Charleston Counties. The ocean shoreline extends the entire 79 mile length of Charleston County and consists of sandy beaches fronting barrier islands and keys. The 1,209 miles of the bay/estuary zone in this area contain an extensive system of wetlands and wide marshes created by a number of rivers which drain the inland swamps and meander toward the sea. These marshes make access to many of the beaches difficult.

The Beaufort-Lower South Carolina area is characterized by its vast system of coastal rivers, marshes, waterways and islands. Most of the area is undeveloped and inaccessible with the exception of Beaufort which lies at the center of a large grouping of marshy islands. Only

39 miles of the coastline area faces the ocean, almost all in Beaufort County; the entire length is composed of sandy beach. Of the remaining 1,027 miles of coastline in the bay/estuary zone, only 8 miles total are beach in character; the rest consists of vast systems of wetland and marsh.

The Savannah-Northern Georgia Coastal area extends from the Savannah River estuary southward to the St. Catherines Sound. As all of the Georgia coastal area, this area consists of the broad coastal plain separated from the Atlantic Ocean by a ridge of barrier islands. The barrier islands, similar to those in Beaufort County to the north, are characterized by sandy beaches facing the ocean and broad low marsh areas intersected by numerous meandering tidal streams or sounds. Of the total 55 miles of shoreline within this area, 23 miles consist of sandy beach facing the ocean. The remaining 32 miles are characterized by wetland and marsh. The city of Savannah is approximately 15 miles inland from the ocean, separated from it by the Wilmington and Tybee Islands.

The Southern Georgia Coastal area extends from St. Catherines Sound southward to St. Marys Entrance at the Florida line, and contains numerous barrier islands commonly referred to as Georgia's "Golden Isles". These islands, the larger of which are from 2 to 3 miles wide, are situated between sounds. The barrier islands contain relatively high dunes; some dunes on Cumberland Island, the largest of the Georgia islands, are over 50 feet high. The total shoreline of the Southern Georgia Coastal area is 149 miles, 69 miles of which faces the ocean. Of the ocean shoreline, 64 miles is sandy beach. An additional 10 miles of the 80 mile bay/estuary shoreline zone is also classed as beach.

The Northern Florida Atlantic Coast area extends from the St. Marys River at the Georgia line southward to the Matanzas Inlet and consists of barrier islands or barrier beach broken occasionally by inlets. The barrier sandy beaches, which extend 71 miles along this area's ocean coastline, are generally backed by low tidal marshes or lagoons. Below the mouth of the St. Johns River, the ocean coastline is generally straight and unbroken by tidal inlets down to the St. Augustine Inlet. The beach in this portion of the area is composed of fine hard sand with a minimum of shell content. Below the St. Augustine Inlet there are the barrier islands of Conch and Anastasia. The low marsh shoreline of the area totals 772 miles in length, all located along the mainland coast and back areas of the barrier islands.

The Cape Canaveral area extends from the Matanzas Inlet southward to Sebastian Inlet and includes the Cape Canaveral area. The ocean shore is unbroken from the Matanyas Inlet to Ponce de Leon Inlet south of Datona Beach, the longest and widest natural beach area on the entire Atlantic Coast. The total ocean shoreline of the area is 139 miles, consisting all of sandy beach. The 410 mile length of bay/estuary shoreline in this mid-Florida area consists almost entirely of marshy lagoon. Beginning in central Volusia County along the Halifax River and southward, broad marsh areas begin to reappear between the barrier islands and the mainland.

The Southern Florida Atlantic Coast area extends from the Sebastian Inlet southward along the Dade County shore area to Key Biscayne, and includes the Florida Keys to Key West. Altogether there are 169 miles of sandy beach ocean coastline along the barrier islands down to Virginia Key and Key Biscayne. Heavy mangrove vegetation occurs on the western parts of these two keys as well as on the keys at the south end of Biscayne Bay and the mainland shore of the Biscayne Bay. The 215 miles of ocean shoreline of the Florida Keys on the Straits of Florida have very few sandy beaches; most beaches are artificially placed. The existing bottom off the Atlantic side of the Keys is flat rock almost entirely devoid of sandy material.

(2) Land Ownership

Atlantic Coast Region

Nearly two-thirds of the entire Atlantic Coast shoreline is privately owned; however, a greater proportion of the

North Atlantic region shoreline is in private ownership than that of the South Atlantic region as indicated in Table 18. In the North Atlantic region much of the public ownership is concentrated along the coasts of Massachusetts, Long Island, New York City, New Jersey, Delaware and Maryland. Most of this ownership is in the form of recreation areas, wildlife conservation areas and military or transportation-related facilities. In the South Atlantic region about 30 percent of the shoreline is in public ownership, again in the form of recreation areas, wildlife conservation areas and military facilities. In North Carolina, some remote inaccesible areas of shoreline are classed as uncertain, pending delineation and determination of ownership by the State; upon determination these areas will be classed either as private or State/public lands.

Private ownership within the South Atlantic region averages only 45 percent of the total shoreline, with the greater proportion of this being along the Georgia and Florida coasts. Public ownership is highest in the Outer Banks, Cape Canaveral and Charleston areas which have a high concentration of public recreation and conservation areas as well as military and aerospace facilities.

(3) Land Use

The type of land use and the intensity of development varies widely throughout the Atlantic Coast region, from

Table 18 Land Ownership of the Atlantic Coast Region Shoreline

Area	Total Length of Shoreline Miles	Federal Miles	Federal %	State/Local Miles	State/Local %	Private Miles	Private %
Maine Coastal Basin	1,900	10	0.5	10	0.5	1,880	99.0
Southern Maine and Coastal New Hampshire	640	12	1.9	60	9.4	568	88.7
Southeastern New England	1,540	100	6.5	225	14.6	1,215	78.9
Connecticut	270	5	1.9	50	18.5	215	79.6
Southeastern New York Metropolitan	638	34	5.3	202	31.7	402	63.0
Northern New Jersey	85	14	16.5	13	15.3	58	68.2
Coastal New Jersey	384	44	11.5	111	28.9	229	59.6
Delaware River Basin	167	31	18.6	34	20.3	102	61.1
Chesapeake Bay Area	3,076	335	10.9	182	5.9	2,559	83.2
TOTAL-North and Mid-Atlantic Region	8,700	585	6.7	887	10.2	7,228	83.1
Currituck-Albemarle Sound	709*	14	2.0	0	-	319	45.0
Outer Banks-Pamlico Sound	2,282*	448	19.6	40	1.8	475	20.8
Onslow-Pender County	293*	94	32.1	6	2.0	116	39.6
Cape Fear	377*	13	3.4	13	3.4	132	35.0
Myrtle Beach	709*	4	0.6	189	26.7	389	54.9
Charleston	1,288*	366	28.4	452	35.1	263	20.4
Beaufort-Lower South Carolina	1,066*	65	6.1	811	76.1	180	17.2
Savannah-Northern Georgia Coastal	55	13	23.6	1	1.8	41	74.6
Southern Georgia Coastal	149	16	10.7	22	14.8	111	74.5
Northern Florida Atlantic Coast	970	30	3.1	23	2.4	917	94.5
Cape Canaveral	549	139	25.3	10	1.8	400	72.9
Southern Florida Atlantic Coast	925	3	0.3	47	5.1	875	94.6
TOTAL-South Atlantic Region	9,372	1,025	12.9	1,614	17.2	4,218	45.0

* Mileages do not total because ownership is uncertain for some estuarine areas in North Carolina.

the many islands along the Maine coast that remain in their natural state, to the dense urban development along the New York-New Jersey Metropolitan coast area, to the open beach areas along the South Atlantic Coast region, to the developed beaches of the Palm Beach-Miami, Florida area. The following table indicates the miles of shoreline used for both public and private recreation, non-recreation development and that which remains undeveloped. The public recreation category includes shoreline that is owned by Federal, State, county and municipal governments for recreation purposes in the form of parks and beaches. (Recreation resources are discussed more thoroughly later in this section.) Privately-owned recreation shoreline areas include those used for resort facilities, marinas, golf courses, etc. which are non-Federally owned. Non-recreation developed shoreline includes industrial, commercial and transportation facilities (ports, as well as military areas related to transportation and defense), urban residential areas and vacation summer home communities. Agriculture cropland is included as a non-recreation development shoreline use. Undeveloped shoreline areas include not only those remaining in their natural state but also include those maintained by Federal and State agencies as wildlife conservation and management areas. (Conservation areas are discussed more thoroughly later in this section.)

Table 19 Shoreline Use in the Atlantic Coast Region (in Miles)

Area	Public Recreation	Private Recreation	Non-Recreation Development	Undeveloped	Total
Maine Coastal Basin	5	445	250	1,200	1,900
Southern Maine and Coastal New Hampshire	16	552	12	60	640
Southeastern New England	285	1,070	105	80	1,540
Connecticut	30	225	15	0	270
Southeastern New York Metropolitan	210	70	250	108	638
Northern New Jersey	28	0	48	9	85
Coastal New Jersey	229	35	10	110	384
Delaware River Basin	70	0	4	93	167
Chesapeake Bay Area	179	201	1,779	917	3,076
TOTAL-North and Mid-Atlantic Region	1,056	2,598	2,460	2,586	8,700
Currituck-Albemarle Sound	0	25	73	611	709
Outer Banks-Pamlico Sound	83	157	137	1,905	2,282
Onslow-Pender County	3	49	15	226	293
Cape Fear	12	90	14	261	377
Myrtle Beach	36	16	188	469	709
Charleston	22	7	198	1,061	1,288
Beaufort-Lower South Carolina	26	27	195	818	1,066
Savannah-Northern Georgia Coastal	3	1	0	51	55
Southern Georgia Coastal	14	5	0	130	149
Northern Florida Atlantic Coast	53	36	110	771	970
Cape Canaveral	84	1	308	156	549
Southern Florida Atlantic Coast	68	117	229	511	925
TOTAL-South Atlantic Region	404	531	1,467	6,970	9,372

The Maine Coastal Basin land use is characterized as generally rural or small town in nature, lacking major urban areas and concentrations of population. It is the least densely populated area in the North Atlantic region. Much of the shoreline remains undeveloped; recreation and tourism are important to the economy of the area. Commercial as well as sport fishing are also features of this area.

The Southern Maine and Coastal New Hampshire shoreline is primarily devoted to recreation. Portland, Maine, is the primary urban center along the coastline of this area having shoreline urban-industrial-transportation development. This area is a transition from the undeveloped shores of upper Maine to the developed shores to the south of Boston.

The Southeastern New England area contains much summer recreational/summer residential shoreline use, including several Federal, State and municipal recreation areas. However, one of the outstanding features of this shoreline area consists of the intense development associated with the Boston Harbor complex, the Providence-Fall River-Narragansett Bay area and the Bedford, Massachusetts, urban area. Proportionately, only a small amount of the total shoreline of this entire area remains undeveloped.

The Connecticut shoreline, similar to the New England area above, is a mixture of summer recreational/residential, permanent residential, public recreational and commercial-industrial-transportation facilities. Public beaches attract the large numbers of people living within the area, with 10 million annual visits having been recorded for 18 cooperative beach projects within the area. Residential development along the shoreline consists generally of private associations and privately-owned homes, both seasonal and year-round, similar to the New England area.

The shoreline of the Southeastern New York Metropolitan area is one of great diversity. In addition to the intense commercial-industrial-transportation facilities located on the shoreline adjacent to the New York City area are the open beach areas along the Westchester and Long Island shorelines which provide outdoor recreation and aesthetic pleasure to the vast concentrations of population living in this area. Annual attendance at beaches in the New York City area in recent years has exceeded 30 million even though water quality has been marginal for swimming. Staten Island beaches draw about one million people annually, Coney Island about 10 million people and the Rockaway beaches about 20 million people. Some 210 miles of shoreline are available as public recreation facilities ideal for most forms of beach and water-contact recreation, as well as private recreation facilities such as marinas, particularly on Long Island. In portions of the area undisturbed wetlands also remain. Several wildlife management areas are located on Long Island.

In Northern New Jersey, intense urban development -- piers, skyscrapers, bridges--is the predominant characteristic over one-half of the shoreline of the entire area is used for commercial-industrial-transportation facilities. Extensive port facilities line most of the waterfront in the Elizabeth, Newark and Jersey City reaches. The amount of waterborne commerce in this section is the highest of the entire North Atlantic region. A substantial portion of the area's coastal zone is also given over primarily to solid waste disposal. Very little of the lower portions of the area's shoreline is available for recreation uses.

The Coastal New Jersey shoreline land use is for the most part residential and recreational in nature. The barrier beach is so heavily developed that virtually no vacant beachfront exists, except for public-owned recreation facilities and scattered vacant parcels around inlets.

Conservation and wildlife management areas also are significant in this area. Outside of these reserved areas, the marshlands and portions of the mainland facing the barrier beaches have recently begun to be developed by private owners as lagoons providing marinas, vacation homes and boating facilities.

The Delaware River Basin shoreline use ranges from highly developed industrial-commercial-transportation facilities on both banks in the northern reaches from Trenton southward to Wilmington, Delaware. Fourteen major ports are located in this section, handling a high volume of waterborne commerce in this Mid-Atlantic region. Below this section the shoreline use is primarily for wetland conservation. A large portion of the wetlands has already been acquired by state and Federal agencies and by private conservation groups.

The Chesapeake Bay area can best be separated into two sections, the first consisting of the Bay proper and its estuary system of major tributaries and a second section consisting of the coastal zones of Delaware, Maryland and Virginia which face the ocean. The Bay/estuary section consists largely of extensive wetlands on the eastern shore and banks, bluffs and wetlands on the western shore.

The ocean coastline within this Bay area is used primarily for recreation. Half of the beach is used for public recreation. Rehoboth Beach, Delaware; Ocean City, Maryland; and Virginia Beach, Virginia are each their state's major summertime outdoor recreation centers. The expanding development of private residential-recreational facilities is increasing along with ocean front areas.

The Currituck-Albemarle Sound area contains large expanses of undeveloped wetlands, over half of whichare in uncertain ownership, awaiting resolution in the courts whether the areas are privately or State-owned. The areas bordering the Currituck Sound are experiencing increased permanent home and vacation cottage development, primarily from the proximity of the Norfolk Metropolitan area to the north.

The Outer Banks-Pamlico Sound area is principally recreation-oriented, with its miles of sandy beaches, waterways and estuaries which attract swimmers, boaters and sport fishermen in the summer months. Considerable beach areas along the ocean lie within the Federal recreation areas of Cape Hatteras and Cape Lookout National Seashores. Cape Hatteras National Seashore accomodates over 2 million visitors annually. Additional recreation lands along the ocean beach are classed as privately owned. These areas are increasingly being developed into recreation-tourism or summer cottage-vacation home centers, particularly in the Kitty Hawk-Nags Head area.

The Onslow-Pender County area contains the Federally-owned Camp Lejeune Marine Corps Base which occupies about 20 percent of Onslow County, and is located around the New River estuary. Public recreation land use within the area consists solely of Hammocks Beach State Park. Onslow Beach, being a part of Camp Lejeune, is primarily used for practice military operations. However, a recreation area, restricted to military personnel (and classed here as private recreation accordingly), is located on the beach area. The remaining shoreline zones of this area are largely private recreation (summer resort beaches and vacation facilities), non-recreation developed (in the towns located along the beach and estuary area) or undeveloped (including the two state wildlife management areas in marsh areas).

The Cape Fear area contains very little public beach along its shoreline. Only at the Fort Fisher Historic Site, the relatively new Masonboro State Park, and the two towns of Carolina Beach and Wrightsville Beach are there public recreation areas of any extent. Many stretches of the ocean shoreline throughout this entire area are experiencing considerable development in the form of seasonal vacation and permanent cottages and homes, as well as hotel/motel, commercial and resort facilities. Development on the mainland shoreline is primarily permanent residences and private recreation facilities. Remaining shoreline areas consist of considerable undeveloped marsh areas, some of which are of uncertain ownership.

The ocean shoreline of the Myrtle Beach area contains the "Grand Strand" area which is a 50-mile seashore used extensively for recreation. Much of this section is developed either with private summer home residences and developments or with private resort, hotel/motel, and commercial facilities. Below and along the Winyah Bay nearly all the area's shoreline consists of undeveloped marsh islands with ribbon beaches. Little use is made of this section, except by surf fishermen that gain access by boat. Public recreation shoreline areas are limited to two state parks.

Many areas along the Charleston area shoreline remain in an undeveloped natural state due to a lack of highway access. Part of this section is occupied by the Cape Romain National Wildlife Refuge, however, other parts are owned by corporations or individuals. Edisto Beach State Park is the only publicly owned beach within this entire Charleston area. Francis Marion National Forest occupies a large section within this area.

The Beaufort-Lower South Carolina area has vast estuary and back bay sections that are undeveloped. Some of this area is devoted to conservation and wildlife management. Along the ocean shoreline only Hunting Island Beach State Park is publicly owned for recreational use. Additional privately owned beach along the area's shoreline is either publicly used or reserved for private use. Hilton Head Island, particularly, is known for its resort/country club communities and facilities.

Outside metropolitan Savannah, most of the Savannah-Northern Georgia Coastal area shoreline is classified largely as undeveloped. Many areas are inaccessible except by boat and are uninhabited. One area, Wassaw Island, is occupied by a Federal wildlife refuge. Public recreation land use is limited mostly to two areas, Fort Pulaski National Monument and the recently established Richmond Hill State Park.

The Southern Georgia Coastal area shoreline is similarly mostly undeveloped, remaining in its natural marshy state. Several portions of this marsh are utilized for Federal, state and private wildlife management areas and preserves. These islands have a suburban residential/resort type development as well as extensive private and public recreational facilities. Jekyll Island is now State owned as a park and has been increasingly developed by both state and private funds. Cumberland Island is now Federally administered as a National Seashore.

The Northern Florida Atlantic Coast is dominated by the urban centers of Jacksonville, Fernandina Beach and St. Augustine and the nearby tourist/recreation developments. However, long shoreline stretches still remain undeveloped. Some of these areas are preserved by the State in their natural state. Public recreation land use predominates along many areas of the sandy beach ocean shoreline. Several state parks are located along the shore of this area.

The Cape Canaveral area shoreline extends from the sparsely developed Flagler County coast southward beyond the highly developed shore areas at Cape Canaveral, and includes the developed shorelines around Daytona Beach, New Smyrna Beach, Cocoa Beach, Melbourne and other smaller Florida Atlantic Coast towns. Public recreation land use in this section is concentrated mostly to the three state parks and beach area in the vicinity of Flagler Beach. The State recently purchased and developed a southerly portion of the beach in this as the Sebastian Inlet State Park.

The Southern Florida Atlantic Coast area is the most intensely developed and populous of the entire State. Although some coast portions, such as north of Vero Beach, are sparsely developed or remain undeveloped (Pelican Island National Wildlife Refuge is located in this section), the stretch between West Palm Beach and Miami is highly developed. Land is increasingly scarce in this lower section of the area. Considerable portions of the shoreline are privately owned and are used for residential purposes and private recreation. The intense urban development of West Palm Beach, Fort Lauderdale, Miami and Miami Beach is characterized by hotel/motel structures lined side by side along the sandy barrier beach. South of this band of intense development below Miami, the mainland coastline and the southern barrier islands fronting Biscayne Bay are again largely undeveloped, consisting of considerable stands of mangrove growth. The Florida Keys have been increasingly developed for private vacation home sites in recent years particularly on Key Largo. Three state parks are located in the island chain, and many of the undeveloped islands are part of three Federal wildlife management areas. On Key West the U.S. Navy's Key West Naval Station occupies the extreme southwesterly tip of the island. Publicly owned beaches on Key West are located on the south side of the island. The remaining island shoreline, like much of the inhabitable part of the chain, is privately owned.

(4) Military Uses

There is extensive military ownership and use of the coastal zone area along the Atlantic Coast. Facilities located on the coast of this region are listed in Table 20 (some of the facilities listed are not currently active and may be idle or used for other purposes, such as recreation or wildlife conservation).

Military operations in coastal areas may include test flights, refueling, all weather fleet training, all weather training drones, carrier and submarine operations, rockets, bomb anti-submarine practice and anti-aircraft and surface gunnery. Military operations which may affect normal use of coastal areas are indicated in such guides as the Notice to Mariners Publications, U.S. National Ocean Survey maps, and U.S. Naval Oceanographic Office maps and publications.

(5) Recreation Resources

The Atlantic Coast region is richly endowed with natural recreation resources. The abundance and diversity of these resources, both publicly and privately owned, make it difficult to prepare a complete inventory or to develop a thorough regional report and analysis. For these reasons, this discussion of recreational resources indicates the values and distinctive characteristics in

Table 20 Military Facilities of the Atlantic Coast Region

Area

Facility

Maine Coastal Basin Area

Southern Maine and Coastal New Hampshire Area
- Portland Naval Shipyard
- Brunswick Naval Air Station
- Pease Air Force Base

Southern New England Area
- Nahant Coast Guard Lifeboat Station
- Fort Heath
- Boston Naval Shipyard
- Boston Naval Hospital
- Boston Army Base
- Fort Warren
- Boston Coast Guard Base
- Boston Naval Shipyard (South Annex)
- Boston Naval Ammunition Depot
- Scituate Coast Guard Station
- South River Air Force Station
- Quonset Point Naval Air Station
- Davisville Naval Construction Battalion Center
- Melville Naval Station
- Newport Naval Station
- Charlestown Auxiliary Naval Air Station

Connecticut Area
- U.S. Coast Guard Academy
- New London Naval Submarine Base

Southeastern New York Metropolitan Area
- Fort Wadsworth
- Miller Auxiliary Army Air Field
- Fort Jay Coast Guard Station
- Suffolk County Air Force Base
- Fort Slocum
- Fort Hamilton
- Fort Totten
- Fort Tilden
- Fort Jay
- New York Naval Air Station (Floyd Bennett Field)
- Brooklyn Army Terminal
- Brooklyn Naval Station

Table 20 (cont.) Military Facilities of the Atlantic Coast Region

Northern New Jersey Area
- Raritan Arsenal
- Bayonne Military Ocean Terminal

Coastal New Jersey Area
- Fort Hancock
- Fort Monmouth
- Cape May Coast Guard Receiving Station

Delaware River Basin Area
- Cape Henlopen Military Reservation
- Bethany Military Reservation

Chesapeake Bay Area
- Upper Bay-Susquehanna River Basin Area
    - Bainbridge Naval Training Center
    - Edgewood Arsenal
    - Aberdeen Proving Grounds
    - Army Chemical Center
    - U.S. Coast Guard Depot
    - Baltimore Army Ordnance Depot
    - Fort Holabird
    - Annapolis Naval Ship Research and Development Center
    - U.S. Naval Academy
    - Patuxent Naval Air Test Center
    - Wallops Island Station (NASA)

Potomac River Basin Area
- Fort Belvoir
- Quantico Marine Corps Air Station

Rappahannock-York River Basins Area
- Cape Peary Army Reservation
- Langley Air Force Base (NASA)

James River Basin Area
- Fort Eustis
- Fort Monroe
- Fort Story
- Norfolk Naval Air Station
- Norfolk Naval Station
- Little Creek Amphibious Base
- Norfolk Naval Ammunition Depot
- Portsmouth Naval Hospital
- Portsmouth Naval Shipyard
- Oceana Naval Air Station
- Camp Pendleton (Army)

Table 2C (cont.) Military Facilities of the Atlantic Coast Region

Currituck-Albemarle Sound Area
- Elizabeth City Coast Guard Naval Air Station

Outer Banks-Pamlico Sound Area
- Cherry Point Marine Corps Air Station

Onslow-Pender County Area
- Camp Lejeune Marine Corps Base

Cape Fear Area
- Sunny Point Army Terminal
- Banks Channel Coast Guard Station

Myrtle Beach Area
- Myrtle Beach Air Force Station

Charleston Area
- Charleston Naval Station
- Charleston Polaris Base
- Charleston Army Depot
- Coast Guard Loran Station

Beaufort-Lower South Carolina Area
- Beaufort Marine Corps Air Station
- Parris Island Marine Corps Base

Savannah-Northern Georgia Coastal Area
- Hunter Army Air Field

Southern Georgia Coastal Area
- Glynco Naval Air Station

Northern Florida Atlantic Coast Area
- Mayport Naval Station
- Jacksonville Naval Air Station
- Cecil Field Naval Air Station
- Naval Air Gunners School
- Craig Army Air Field

Cape Canaveral Area
- Patrick Air Force Base
- Cape Kennedy Air Force Station
- John F. Kennedy Space Center (NASA)

Southern Florida Atlantic Coast Area
- Homestead Air Force Base
- Key West Naval Station
- Key West Naval Air Station

general terms, and does not attempt to provide a base for detailed statistical comparisons. Information for this discussion is drawn in part from Chapter 12 of the Coastal and Offshore Environment Inventory: Cape Hatteras to Nantucket Shoals, Complement Volume, Marine Publication Series No. 3, University of Rhode Island, and from "A Socio-Economic Environmental Baseline Summary for the South Atlantic Region between Cape Hatteras, North Carolina, and Cape Canaveral, Florida," prepared by Planners Incorporated, Washington, D.C.

The vast recreation resources of the Atlantic Coast region are available not only to the large concentrations of population on the East Coast but also draw large numbers of tourists from most other sections of the Nation. The following table gives estimates of the summer days of participation in 1970 for seven major outdoor recreation activities.

The distribution of the existing Federal and State recreation areas (National Seashores, parks, monuments, historic sites, etc.) is shown on the accompanying two maps. Table 22 follows, giving the name, location and acreage (where available) of major Federal and State recreation areas as well as all Federal or State beaches. In addition to these areas, throughout the Atlantic coast region are various county, municipal and local public recreation areas that have been established for utilization largely by local populations.

Table 21 Number of Participants and Days of Participation for Selected Outdoor Recreation Activities: Northeast States, South Atlantic States, and U.S., 1970*

Region and Characteristic	% of Pop.	Recreation Days (1000's)	Days per Person
Boating			
U.S.	24.2	388,212	2.5
Northeast**	22.7	89,202	2.4
South Atlantic	20.1	57,330	2.4
Swimming			
U.S.	43.6	1,423,010	9.2
Northeast	49.5	382,462	10.4
South Atlantic	39.0	211,265	9.0
Wildlife & Bird Photography			
U.S.	2.9	37,828	0.2
Northeast	3.0	11,652	0.3
South Atlantic	2.1	4,104	0.2
Fishing			
U.S.	28.4	514,669	3.3
Northeast	20.2	83,898	2.3
South Atlantic	29.4	87,353	3.7
Camping			
U.S.	19.9	354,769	2.3
Northeast	13.3	65,721	2.4
South Atlantic	13.9	34,878	1.5
Nature Walks			
U.S.	17.3	337,092	2.2
Northeast	17.3	81,078	2.2
South Atlantic	14.3	49,253	2.1
Picnicking			
U.S.	47.6	479,993	3.1
Northeast	47.5	122,515	3.3
South Atlantic	39.5	61,387	2.6

* Population 12 years of age and older.

** The Northeast States is here defined to include both the New England and Mid-Atlantic Census Divisions (including Pennsylvania).

Source: U.S. Department of the Interior, Bureau of Outdoor Recreation. The 1970 Survey of Outdoor Recreation Activities, Washington, D.C., 1972a).

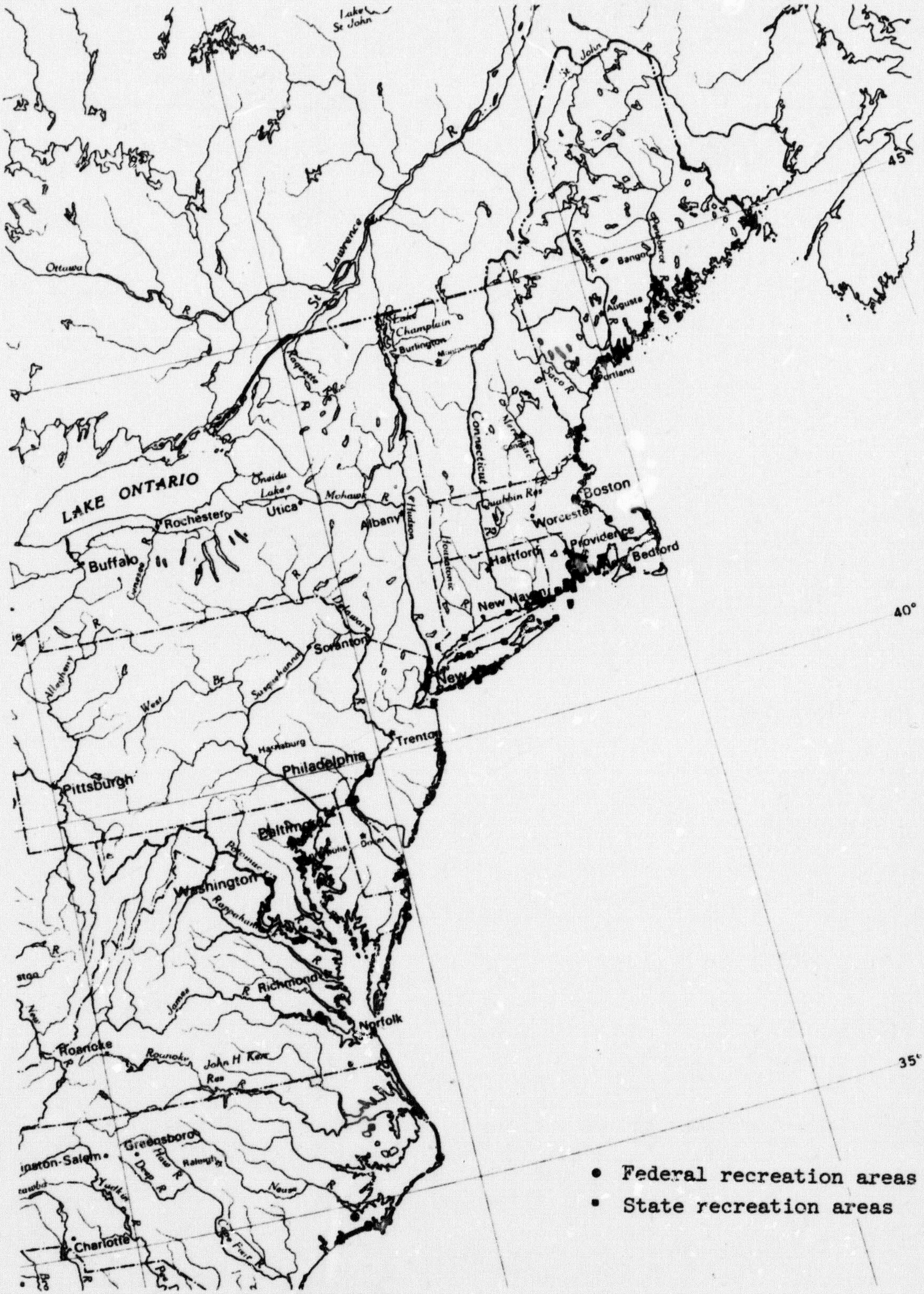

Lake St John
Ottawa R
St Lawrence R
St John R
Kennebec
Penobscot R
Bangor
Augusta
Portland
Saco R
Lake Champlain
Burlington
Raquette
LAKE ONTARIO
Oneida Lake
Mohawk R
Hudson
Connecticut
Merrimack
Quabbin Res
Housatonic
Boston
Worcester
Providence
New Bedford
Hartford
New Haven
New York
Rochester
Buffalo
Genesee R
Utica
Albany
Scranton
Delaware
Allegheny
West Br
Susquehanna
Harrisburg
Philadelphia
Trenton
Pittsburgh
Baltimore
Washington
Potomac R
Rappahannock
Richmond
James R
Norfolk
Roanoke
Roanoke R
John H Kerr Res
Greensboro
Winston-Salem
Haw R
Deep R
Raleigh
Neuse R
Yadkin R
Charlotte
Cape Fear R
45°
40°
35°
● Federal recreation areas
▪ State recreation areas

Figure 65 Federal and State Recreation Areas in the North and Mid-Atlantic Region

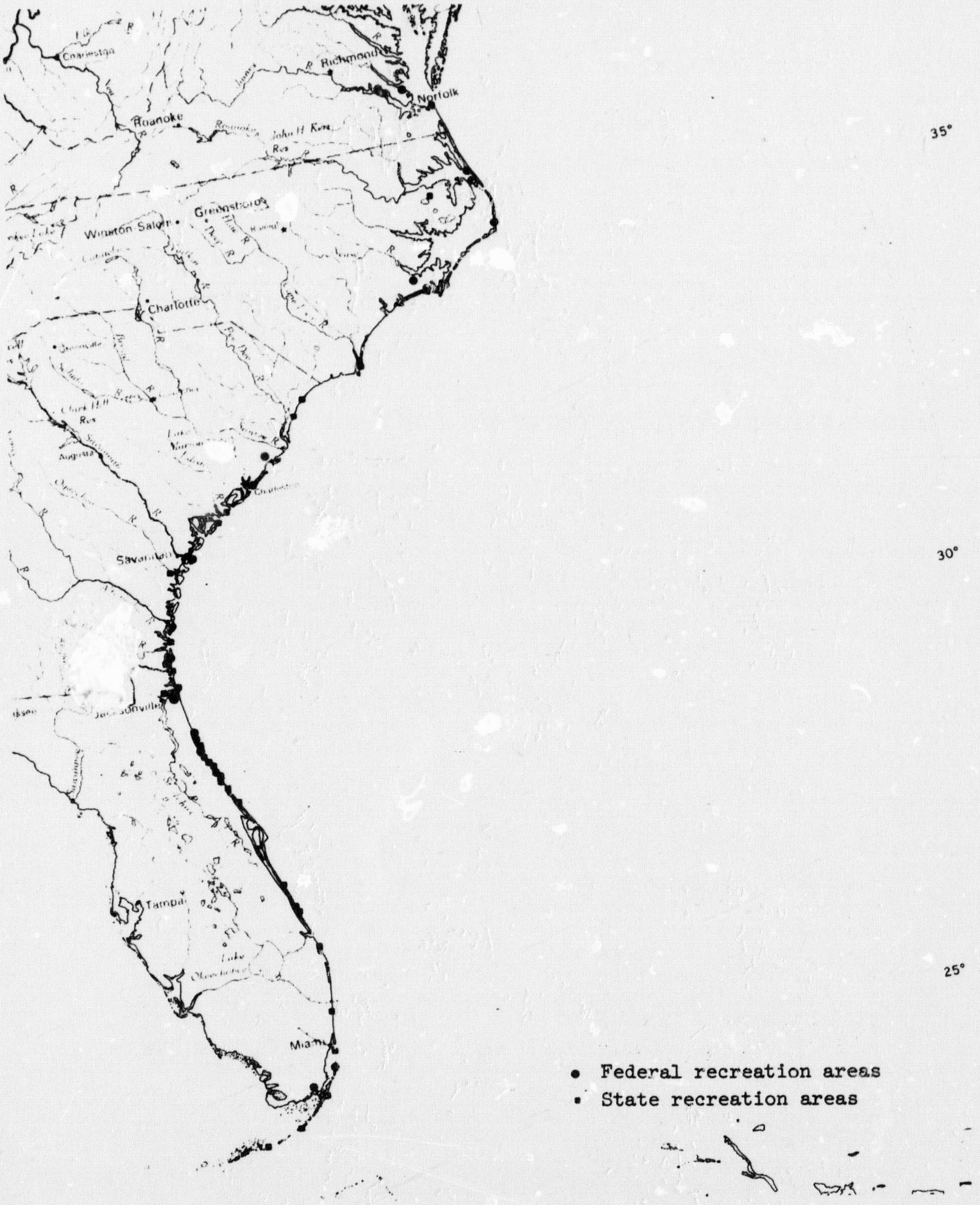

Charleston
Richmond
Norfolk
Roanoke
John H Kerr Res
35°
Winston Salem
Greensboro
Charlotte
Clark Hill Res
Augusta
Lake Marion
Savannah
30°
Jacksonville
Tampa
Lake Okeechobee
25°
Miami
● Federal recreation areas
▪ State recreation areas

Figure 66 Federal and State Recreation Areas in the South Atlantic Region

Table 22 Existing State and Federal Recreation Areas

Area Name	Location	Acreage
Maine Coastal Basin Area		
Acadia National Park	Hancock-Knox Co.	34,350
Lamoine State Park	Hancock Co.	55
Cobscook Bay State Park	Washington Co.	868
Ouoddy Head State Park	Washington Co.	481
Camden Hills State Park	Waldo-Knox Co.	5,004
Moose Point State Park	Waldo Co.	183
Warren Island State Park	Waldo Co.	70
Fort Knox State Park	Waldo Co.	124
Reid State Park	Sagadahoc Co.	768
Popham Beach State Park	Sagadahoc Co.	529
Southern Maine and Coastal New Hampshire Area		
Wolf Neck State Park	Cumberland Co., Maine	233
Two Lights State Park	Cumberland Co.	40
Crescent Beach State Park	Cumberland Co.	174
Wallis Sands State Park	Rockingham Co., New Hampshire	118
Rye Harbor State Park	Rockingham Co.	63
Hampton Beach State Park	Rockingham Co.	
Southeastern New England Area		
Salisbury Beach State Reservation	Essex Co., Massachusetts	520
Crane Beach State Reservation	Essex Co.	
Misery Islands State Reservation	Exxex Co.	
Cape Cod National Seashore	Barnstable Co., Mass.	27,000
Scussett Beach State Reservation	Barnstable Co.	380
Roland C. Nickerson State Park	Barnstable Co.	1,779
Oak Bluffs State Beach	Dukes Co., Mass	
Fort Phoenix Beach State Reservation	Bristol Co., Mass.	23
Demarest Lloyd State Park	Bristol Co.	222
Horseneck Beach State Reservation	Bristol Co.	385
Colt State Park	Bristol Co., Rhode Island	455
Haines Memorial State Park	Bristol Co., R.I.	
Brenton Point State Park	Newport Co., R.I.	
Fort Wetherill State Park	Newport Co.	
Fort Adams State Park	Newport Co.	
Roger W. Wheeler Memorial State Beach	Washington Co., Rhode Island	27
Scarborough State Beach	Washington Co.	23
East Matunuck State Beach	Washington Co.	102
Misquamicut State Beach	Washington Co.	57
Burlingame State Park	Washington Co.	2,100
Block Island State Beach	Washington Co.	18
Fishermens Memorial State Park	Washington Co.	
Goddard Memorial State Park	Kent Co., Rhode Island	472
Squantum Woods State Park	Providence Co., R.I.	

Table 22 (cont.) Existing State and Federal Recreation Areas (cont.)

Connecticut Area

Fort Griswold State Park	New London Co., Conn.	
Harkness Memorial State Park	New London Co.	
Rocky Neck State Park	New London Co.	561
Hammonasset State Beach	New Haven Co., Conn.	918
Sherwood Island State Park	Fairfield Co., Conn.	211

Southeastern New York Metropolitan Area

Fire Island National Seashore	Long Island, N.Y.	
Jones Beach State Park	Nassau Co., N.Y.	2,413
Robert Moses State Park	Suffolk Co., N.Y.	1,000
Gilgo State Park	Suffolk Co.	
Captree State Park	Suffolk Co.	
Heckscher State Park	Suffolk Co.	
Caumsett State Park	Suffolk Co.	
Sunken Meadow State Park	Suffolk Co.	1,266
Wildwood State Park	Suffolk Co.	699
Orient Beach State Park	Suffolk Co.	
Hither Hills State Park	Suffolk Co.	1,755
Montauk Point State Park	Suffolk Co.	

Coastal New Jersey Area

Sandy Hook State Park	Monmouth Co., New Jersey	795
Cheesequake State Park	Middlesex Co., N.J.	
Island Beach State Park	Ocean Co., N.J.	
Barnegat Lighthouse State Park	Ocean Co.	31

Delaware River Basin Area

Cape Henlopen State Park	Sussex Co., Delaware	1,641
Delaware Seashore State Park	Sussex Co.	1,759
Holts Landing State Park	Sussex Co.	33

Chesapeake Bay Area

Upper Bay-Susquehannock-York Basin Area

Assateague Island National Seashore	Maryland-Virginia	
Assateague State Park	Worcester Co., Maryland	680
Janes Island State Park	Worcester Co.	2,875
Elk Neck State Park	Cecil Co., Maryland	1,054
Gunpowder State Park	Baltimore Co., Maryland	963
Sandy Point State Park	Anne Arundel Co., Md.	680
Point Lookout State Park	St. Marys Co., Md.	497

Potomac River Basin Area

Westmoreland State Park	Westmoreland Co., Va.	1,338

James River Basin Area

Seashore State Park	Virginia Beach City, Va.	2,770

Table 22 (cont) Existing State and Federal Recreation Areas (cont.)

Currituck-Albemarle Sound Area		
Pettigrew State Park	Washington Co., No. Ca.	17,367
Outer Banks-Pamlico Sound Area		
Cape Hatteras National Seashore	Dare-Hyde Co., No. Ca.	32,000
Croatan National Forest	Craven-Carteret Co.	152,351
Fort Mason State Park	Carteret Co.	385
Cape Lookout National Seashore	Carteret Co.	25,000
Onslow-Pender County Area		
Hammocks Beach State Park	Onslow Co., No. Ca.	894
Cape Fear Area		
Masonboro State Park	New Hanover Co., No. Ca.	429
Myrtle Beach Area		
Myrtle Beach State Park	Horry Co., So. Ca.	312
Huntington Beach State Park	Horry Co.	2,500
Charleston Area		
Francis Marion National Forest	Charleston-Berkeley Co.	245,000
Edisto Beach State Park	Charleston Co.	1,255
Beaufort-Lower South Carolina Area		
Hunting Island State Park	Beaufort Co., So. Ca.	5,000
Savannah-Northern Georgia Coastal Area		
Jekyll Island State Park	Glynn Co., Georgia	11,000
Crooked River State Park	Camden Co., Georgia	500
Cumberland Island National Seashore		
Northern Florida Atlantic Coast Area		
Fort Clinch State Park	Nassau Co., Florida	1,085
Little Talbot Island State Park	Duval Co., Florida	2,500
Frank B. Butler State Park	St. Johns Co.	53
Anastasia State Park	St. Johns Co.	1,035
Faver-Dykes State Park	St. Johns Co.	752
Cape Canaveral Area		
Flagler Beach State Park	Flagler Co., Florida	145
Tomoka State Park	Volusia Co., Florida	915
Sebastian Inlet State Park	Brevard Co., Florida	

Table 22 (cont.) **Existing State and Federal Recreation Areas (cont.)**

Southern Florida Atlantic Coast Area

Jack Island State Park	St. Lucie Co., Florida	958
Peper State Park	St. Lucie Co.	
Jonathan Dickinson State Park	Martin Co., Florida	9,564
Hugh Taylor Birch State Park	Broward Co., Florida	180
Biscayne Bay National Monument	Dade Co., Florida	
Cape Florida State Park	Dade Co.	900
Everglades National Park	Dade-Monroe Co., Florida	1,400,533
John Pennekamp Coral Reef State Park	Monroe Co.	75,206
Long Key State Park	Monroe Co.	292
Bahia Honda State Park	Monroe Co.	270

Numerous historically-significant submerged shipwrecks are located along the entire Atlantic coast. The age of these wrecks spans a range of over 400 years.

Formerly emergent areas of the Atlantic continental shelf quite probably contain numerous archaeological habitations sites and associated artifacts. Although specific sites have not been identified in the offshore region, many were probably located along the banks of former river channels and relict shorelines which are identifiable submerged features of the modern shelf (see Figure 10).

(6) Conservation Areas

Over 7,400 miles of the Atlantic coast region shoreline length is non-beach in character, and much of this is marsh/wetland. Preservation of this coastal wetland area involves maintaining its natural state for the purposes of nutrient recycling, wildlife habitat, reproduction grounds, flood plain protection and erosion control.

Many of the states along the Atlantic coast are in the process of establishing coastal zone management mechanisms pursuant to the Federal Coastal Zone Management Act of 1972 for the purpose of protecting and regulating the uses that can be made of this important resource. Various States have already established laws that provide for control and delineation of coastal areas of critical concern, and require approval of coastal developments and activities. A listing of some of the States' laws is given in the table below.

Table 23 State Coastal Zone Management-Related Statutes

Maine	Mandatory Shoreline Zoning and Subdivision Control Act of 1971; Land Use Act; Site Selection Act of 1970
New Hampshire	Wetlands Act
Massachusetts	Coastal Wetlands Protection Act of 1965; Conservation Restriction Act of 1970
Rhode Island	Coastal Management Act of 1971; Inter-Tidal Salt Marsh Act; Fresh Water Wetlands Act
Connecticut	Coastal Wetlands Act of 1969
New York	Tidal Wetlands Act of 1973
New Jersey	Wetlands Act of 1970; Major Coastal Facilities Review Act of 1972
Delaware	Coastal Zone Act of 1971; Wetlands Act
Maryland	Wetlands Act of 1970
Virginia	Wetlands Protection Act of 1972; Land Use Policy Act
North Carolina	Coastal Areas Management Act of 1974
South Carolina	
Georgia	Coastal Marshlands Protection Act of 1970
Florida	Environmental Land and Water Management Act of 1972

Cape Hatteras marks the southern boundary of the embayed section of the Atlantic coast. This section is characterized by large indentations (embayments, estuaries, and ponds) and extends northward to Cape Cod. The majority of these estuaries result from drowned river valleys, but the Long Island Sound was enclosed by large coastal structures which have been covered by glacial deposits. Other emergent structures of similar origin include Cape Cod, Martha's Vineyard, Long Island, Block Island and Nantucket Island. The well known bays in this area include the Chesapeake, Delaware, and Narragansett Bays. The coastline north of Cape Cod is irregular, with exposed rocky headlands and unconsolidated beaches interspersed.

The description of nearshore and onshore biology is categorized and discussed briefly by community type (see Table 16 for representative flora and fauna). The discussion of community types is limited to those which might be affected by OCS development. Additional and complementary discussion is given for similar communities in the Gulf of Mexico (Section II B 2 b).

(1) Benthic Algae

Benthic algae, including diatoms and macrophytes figure prominantly in the energy flow of the nearshore community throughout the area. Artificial hard substrates such as pilings and rocky structures as well as silty and sandy substrates are colonized by these benthic algae. Pomeroy (1959, in VIMS, 1974) estimated that the productivity of these flora in a Georgia marsh averaged 180-200 the Atlantic Coast region there are various county, municipal and local public recreation areas that have been established for utilization largely by local populations.

(6) Conservation Areas

Over 7,400 miles of the Atlantic Coast region shoreline length is non-beach in character, and much of this is marsh/wetland. Preservation of this coastal wetland area involves maintaining its natural state for the purposes of nutrient recycling, wildlife habitat, reproduction grounds, flood plain protection and erosion control.

Many of the states along the Atlantic Coast are in the process of establishing coastal zone management mechanisms pursuant to the Federal Coastal Zone Management Act of 1972 for the purpose of protecting and regulating the uses that can be made of this important resource. Various states have already established laws that provide for control and delineation of coastal areas of critical concern, and require approval of coastal developments and activities. A listing of some of the States' laws is given in the table below.

Numerous Federal and State conservation-wildlife and environment management areas are already established which serve to preserve large sections of the coastal zone from development pressures. The distribution of the existing Federal wildlife refuges is shown on the accompanying two maps. Table 24 immediately following the map, lists the names of the Federal and State conservation-wildlife management areas and acreage (where available).

(7) Transportation

Major Ports and Shipping

The natural harbors and channels along the Atlantic coast have provided valuable locations for the development and growth of port facilities throughout the entire region. The economic importance of these port facilities has been apparent throughout the Nation's growth and development. The vast quantities of cargo handled through these ports, which economically may be the most significant use of the coastal zone, sustains the industry and economy of far-reaching areas throughout the East Coast and the Nation. Vast quantities of foreign oil imports enter the Delaware River ports, the New York-Northern New Jersey ports and Portland, Maine. Almost all the crude oil imports enter these ports; about one-half the refined petroleum products are imported through the ports of New York-Northern New Jersey. The vast refinery operations located in the Northern New Jersey vicinity together with the importation of foreign oil has resulted in the development of a large specialized industrial complex with unique dependence upon the

(2) Air Quality

Air quality is generally good along the Atlantic coastline. In the vicinity of cities and industrial complexes however, air quality can reach health hazard levels. The major factors affecting air quality are quality and quantities of pollutants emitted, distance from point sources, and meteorological conditions. Extended periods of thermal inversions reduce the vertical mixing in the air column. Pollutants which are emitted during these periods are trapped at lower altitudes and may build to hazardous concentrations. Figure 69 depicts predicted occurrences of heavy pollution based upon observed weather conditions. Table 35 presents the present status of air quality control regions along the Atlantic coast.

Secondary standards (Table 36) for SO_2 have been waived for the duration of the energy shortages the region is now experiencing.

(3) Dredging

Major dredging efforts are underway along the Atlantic coastline. The major goals of most of these activities are replinishment of beach sands and deepening and widening of navigable channels. Other less important objectives include land fill and recreational boat harbor maintenance. For a more expanded discussion of the impacts of these actions on water quality, refer to the section on impacts.

Numerous Federal and State conservation-wildlife and environment management areas are already established which serve to preserve large sections of the coastal zone from development pressure. The distribution of the existing Federal wildlife refuges is shown on the accompanying two maps. Table 24 , immediately following the map, lists the names of the Federal and State conservation-wildlife management areas and acreage (where available).

(7) Transportation

Major Ports and Shipping

The natural harbors and channels along the Atlantic coast have provided valuable locations for the development and growth of port facilities throughout the entire region. The economic importance of these port facilities has been apparent throughout the Nation's growth and development. The vast quantities of cargo handled through these ports, which economically may be the most significant use of the coastal zone, sustains the industry and economy of far-reaching areas throughout the East Coast and the Nation. Vast quantities of foreign oil imports enter the Delaware River ports, the New York-Northern New Jersey ports and Portland, Maine. Almost all the crude oil imports enter these ports; about one-half the refined petroleum products are imported through the ports of New York-Northern New Jersey. The vast refinery operations located in the Northern New Jersey vicinity together with the importation of foreign oil have resulted in the development of a large specialized industrial complex with unique dependence upon the

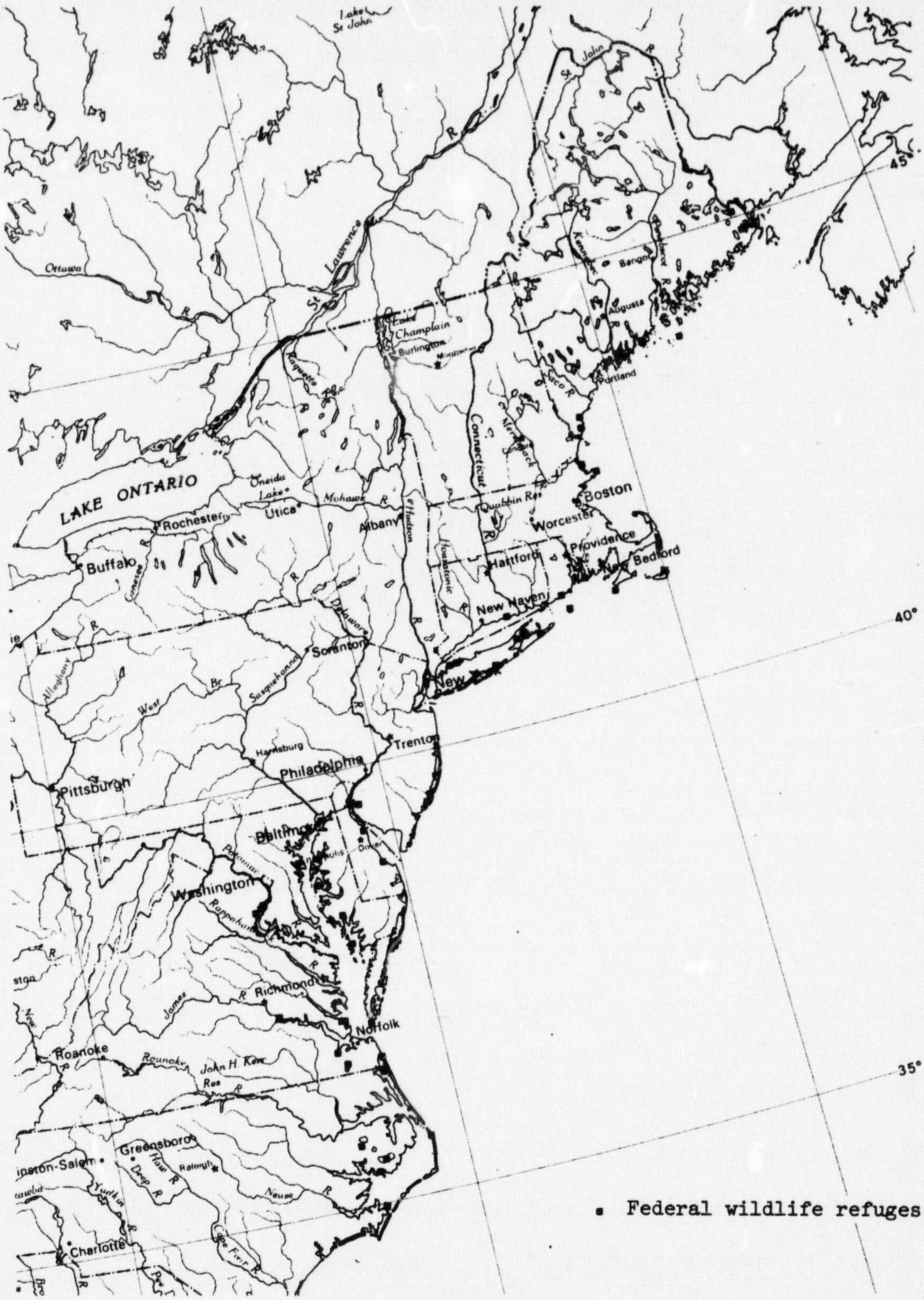

Lake St John
St John R
Ottawa R
St Lawrence R
45°
Bangor
Penobscot R
Kennebec R
Augusta
Lake Champlain
Burlington
Montpelier
Raquette R
Saco R
Portland
Connecticut R
Merrimack R
Concord
LAKE ONTARIO
Oneida Lake
Rochester
Utica
Mohawk R
Albany
Hudson R
Quabbin Res
Boston
Worcester
Providence
Buffalo
Genesee R
Housatonic R
Hartford
New Bedford
New Haven
Delaware R
40°
Scranton
Allegheny R
West Br
Susquehanna R
New York
Trenton
Harrisburg
Philadelphia
Pittsburgh
Baltimore
Annapolis
Dover
Potomac R
Washington
Rappahannock R
Richmond
James R
Norfolk
Roanoke
Roanoke R
John H Kerr Res
35°
Greensboro
Winston-Salem
Haw R
Deep R
Raleigh
Neuse R
Yadkin R
Charlotte
Cape Fear R
■ Federal wildlife refuges

Figure 67 Federal Wildlife Refuges in the North and Mid-Atlantic Region

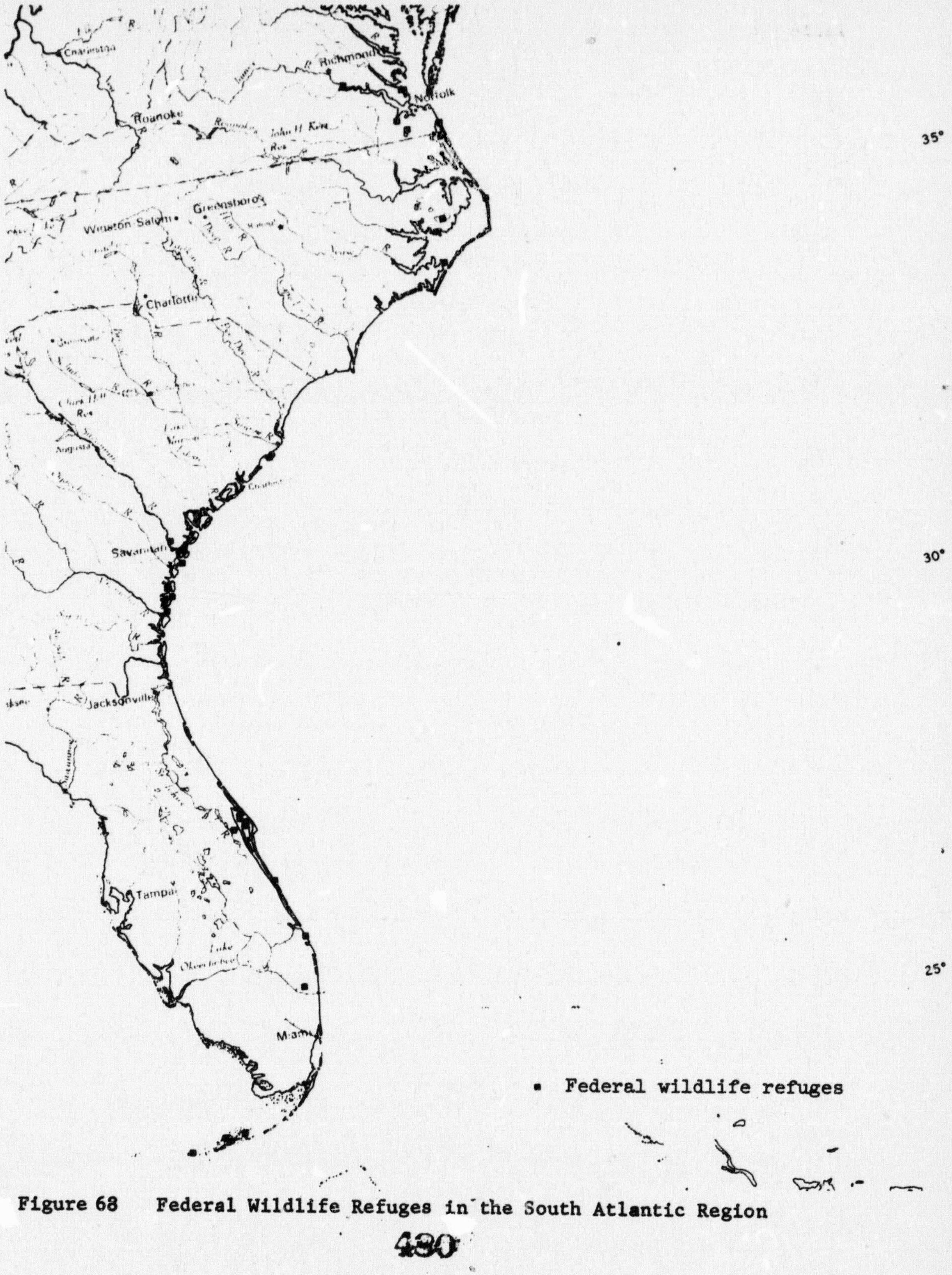

Charleston
Richmond
Norfolk
Roanoke
John H. Kerr Res
Winston Salem
Greensboro
Charlotte
Clark Hill Res
Augusta
Lake Marion
Savannah
Jacksonville
Tampa
Lake Okeechobee
Miami
35°
30°
25°
■ Federal wildlife refuges

Figure 68 Federal Wildlife Refuges in the South Atlantic Region

Table 24 Existing Federal and State Conservation-Wildlife Management Areas

Area Name	Jurisdiction	Acreage
Maine Coastal Basin Area		
Moosehorn National Wildlife Refuge	Maine	22,666
Seal Island National Wildlife Refuge	"	65
Franklin Island National Wildlife Refuge	"	12
Pond Island National Wildlife Refuge	"	10
Southern Maine and Coastal New Hampshire Area		
Rachel Carson National Wildlife Refuge	Maine	1,587
Southeastern New England Area		
Parker River National Wildlife Refuge	Massachusetts	4,650
Thatcher Island National Wildlife Refuge	"	22
Monomoy National Wildlife Refuge	"	2,698
Nantucket National Wildlife Refuge	"	40
Nomans Land Island National Wildlife Refuge	"	620
Wellfleet Bay State Wildlife Sanctuary	"	
Cape Cod Ocean Sanctuary	"	
Sachuest Point National Wildlife Refuge	Rhode Island	71
Block Island National Wildlife Refuge	"	29
Ninigret National Wildlife Refuge	"	28
Sapowet Marsh State Wildlife Preserve	"	
Norman Sanctuary (Audubon Society)	"	
Dutch Island State Management Area	"	
Galilee State Bird	"	
Great Swamp State Management Area	"	
Ninigret State Conservation Area	"	
Burlingame State Management Area	"	
Woody Hill State Management Area	"	
Indian Cedar Swamp State Management Area	"	
Marsh Meadows State Wildlife Preserve	"	
Connecticut Area		
Salt Meadows National Wildlife Refuge		178
Barn Island State Wildlife Management Area		
Great Island State Wildlife Managment Area		
Lords Cove State Wildlife Management Area		
Nott Island State Wildlife Management Area		
Nells Island State Wildlife Management Area		
Charles E. Wheeler State Wildlife Management Area		
Southeastern New York Metropolitan Area		
Target Rock National Wildlife Refuge	Long Island, N.Y.	80
Oyster Bay National Wildlife Refuge	"	3,117
Seatuck National Wildlife Refuge	"	10
Wertheim National Wildlife Refuge	"	149
Conscience Point National Wildlife Refuge	"	60
Morton National Wildlife Refuge	"	187
Amagansett National Wildlife Refuge	"	36
Jamaica Bay Saate Wildlife Refuge	"	

Table 24 Existing Federal and State Conservation-Wildlife Management Areas (cont.)

Northern New Jersey Area

Coastal New Jersey Area

Manohawkin State Fish and Wildlife Management Area		
Stafford Forge State Fish and Wildlife Management Area		
Port Republic State Fish and Wildlife Management Area		
Tuckahoe Corbin City State Fish and Wildlife Management Area		
Beaver Swamp State Fish and Wildlife Management Area		
Peaslee State Fish and Wildlife Management Area		
Barnegat National Wildlife Refuge		3,578
Brigantine National Wildlife Refuge		20,230
Cape May Point Sanctuary (Audubon Society)		
Marmora State Fish and Wildlife Management Area		
Money Island State Fish and Wildlife Management Area		

Delaware River Basin Area

Dennis Creek State Fish and Wildlife Management Area	New Jersey	
Heislerville State Fish and Wildlife Management Area	"	
Egg Island State Fish and Wildlife Management Area	"	
Fortescue State Fish and Wildlife Management Area	"	
Millville State Fish and Wildlife Management Area	"	
Nantuxent State Fish and Wildlife Management Area	"	
Dix State Fish and Wildlife Management Area	"	
Mad Horse Creek State Fish and Wildlife Management Area	"	
Killcohook National Wildlife Refuge	"	
Supawna Meadows National Wildlife Refuge	"	
Bombay Hook National Wildlife Refuge	Delaware	15,111
Prime Hook National Wildlife Refuge	"	6,954
Canal State Wildlife Area	"	
Augustine State Wildlife Area	"	
Appoquinimink State Wildlife Area	"	
Woodland Beach State Wildlife Area	"	
Little Creek State Wildlife Area	"	
Milford Neck State Wildlife Area	"	

Chesapeake Bay Area

Upper Bay-Susquehanna River Basin Area

Assawoman State Wildlife Area	Delaware	
Susquehanna National Wildlife Refuge	Maryland	4
Eastern Neck National Wildlife Refuge	"	2,286
Blackwater National Wildlife Refuge	"	11,627
Martin National Wildlife Refuge	"	4,423
Chincoteague National Wildlife Refuge	Maryland-Virginia	9,439
Wallops Island National Wildlife Refuge	Virginia	3,000
Fishermans Island National Wildlife Refuge	"	1,000
Saxis Island State Wildlife Management Area	"	
Mockhorn Island State Wildlife Management Area	"	
Taylors Island State Wildlfir Area	Maryland	
Fishing Bay State Wildlife Area	"	
Ellis Bay State Wildlife Area	"	
Le Compte State Wildlife Area	"	

Table 24 Existing Federal and State Conservation-Wildlife Management Area (cont.)

Upper Bay-Susquehanna River Basin Area (cont.)		
Linkwood State Wildlife Area	Maryland	
Deal Island State Wildlife Area	"	
Fairmount State Wildlife Area	"	
Cedar Island State Wildlife Area	"	
Wellington State Wildlife Area	"	
E. A. Vaughn State Wildlife Management Area	"	
Potomac River Basin Area		
Patuxent National Wildlife Research Center	Maryland	3,289
Harry Bowen State Wildlife Management Area	"	
Mason Neck National Wildlife Refuge	Virginia	1,495
Marumsco National Wildlife Refuge	"	63
Rappahannock-York River Basins Area		
Plum Tree Island National Wildlife Refuge	Virginia	3,277
James River Basin Area		
Presquile National Wildlife Refuge	Virginia	1,329
Nansemond National Wildlife Refuge	"	208
Back Bay National Wildlife Refuge	"	4,589
Dismal Swamp National Wildlife Refuge	"	49,097
Currituck-Albemarle Sound Area		
Mackay Island National Wildlife Refuge	Va.-N.Ca.	7,024
Outer Banks-Pamlico Sound Area		
Pea Island National Wildlife Refuge		5,915
Pungo National Wildlife Refuge		12,350
Mattamuskeet National Wildlife Refuge		50,180
Swanquarter National Wildlife Refuge		15,501
Cedar Island National Wildlife Refuge		12,526
Gull Rock State Wildlife Management Area		16,856
Dare State Game Land		155,134
Big Pocasin State Game Land		24,115
Goose Creek State Wildlife Management Area		7,099
Onslow-Pender County Area		
Holly Shelter State Game Land		
Angola State Game Land		
Cape Fear Area		
Eagle Island State Wildlife Management Area		2,000
Myrtle Beach Area		
Gapway Bay State Game Management Area	South Carolina	
Kilsock State Game Management Area	"	
Pee Dee State Game Management Area	"	
Biust State Game Management Area	"	
Waccamaw State Game Management Area	"	
Hobcaw Barony Management Area (private)	"	17,500

Table 24 Existing Federal and State Conservation-Wildlife Management Areas (cont.)

Charleston Area		
Cape Romain National Wildlife Refuge	South Carolina	34,218
Cape Romain Wilderness Area	"	28,000
Beaufort-Lower South Carolina Area		
Savannah National Wildlife Refuge	Ga.-So. Ca.	13,173
Tybee National Wildlife Refuge	"	100
Savannah-Northern Georgia Coastal Area		
Wassaw National Wildlife Refuge	Georgia	10,242
Southern Georgia Coastal Area		
Harris Neck National Wildlife Refuge	Georgia	2,687
Blackbeard Island National Wildlife Refuge	"	5,618
Wolf Island National Wildlife Refuge	"	5,126
R. J. Reynolds State Wildlife Refuge	"	
Altamaha Waterfowl Public Hunting Area	"	30,000
Little St. Simons Island Nature Preserve (private)	"	
Okefenokee National Wildlife Refuge	"	377,528
Northern Florida Atlantic Coast Area		
Rollins Bird and Plant Sanctuary	Florida	133
St. Marys River State Aquatic Preserve	"	
St. Johns River State Aquatic Preserve	"	
Cape Canaveral Area		
Merritt Island National Wildlife Refuge	Florida	140,393
St. Johns National Wildlife Refuge	"	2,396
Farmton State Wildlife Management Area	"	
Lake Woodruff National Wildlife Refuge	"	18,417
Southern Florida Atlantic Coast Area		
Pelican Island National Wildlife Refuge	Florida	4,359
Hobe Sound National Wildlife Refuge	"	773
Loxahatchee National Wildlife Refuge	"	145,635
Key West National Wildlife Refuge	"	2,019
Great White Heron National Wildlife Refuge	"	2,764
National Key Deer Refuge	"	4,642

ports of this area. The major volume of general cargo imports and exports is from New York, the Delaware River ports and Baltimore, in that order. Ore imports, primarily iron ore, comes through the Delaware River ports and Baltimore. Coal is exported largely from the Hampton Roads vicinity as well as from Baltimore. Table 25 indicates the volume of commerce in the major Atlantic port areas.

Major Interstate Highways

Interstate 95 links the entire Atlantic Coast region from Maine to Miami. It links the major coastal cities of Portland, Maine; Portsmouth, New Hampshire; Boston, Massachusetts; Providence, Rhode Island; New London, New Haven, Bridgeport, Norwalk and Stamford, Connecticut; New York City; Newark, Jersey and environs; Philadelphia; Wilmington, Delaware; Baltimore; Washington, D.C.; Richmond, Virginia; Savannah, Georgia; Jacksonville, Florida; Palm Beach; ending in Miami. Interstate highways also link these coastal urban areas with inland areas. Interstate 195 connects New Bedford and Fall River, Massachusetts, with Providence. Interstate 93 links Boston with New Hampshire and Vermont. Interstate 76 links Philadelphia with western Pennsylvania and points beyond. Interstate 83 connects Baltimore with points northward, and Interstate 70 connects it with points westward. Interstate spur 270 connects Washington, D.C. with I-70 and points beyond. Interstate 64 connects the Hampton Roads vicinity with Richmond and points westward, and Interstate 26 connects Charleston, South Carolina with Columbia and points inland. Interstate

Table 25 Shipping Commerce, 1971 - Atlantic Areas with Major Ports

Area	Total Commerce (tons)	Principal Port(s)
Maine Coastal Basin	1,013,537	Searsport
Southern Maine/Coastal New Hampshire	33,854,000	Portland, Maine; Portsmouth, N.H.
Southeastern New England	40,934,000	Boston; Providence; Fall River
Connecticut	21,292,600	New Haven; New London; Bridgeport
Southeastern New York/ Northern New Jersey	207,900,000	Port of New York (including New Jersey)
Delaware River Basin	149,839,000	Philadelphia; Paulsboro, & Marcus Hook, N.J.
Chesapeake Bay Area	110,913,000	Baltimore; Norfolk-Newport News;
Outer Banks-Pamlico Sound	1,289,768	Morehead City
Cape Fear	6,050,538	Wilmington
Myrtle Beach	1,190,637	Georgetown
Charleston	6,945,951	Charleston
Beaufort-Lower South Carolina	1,364,000	Beaufort
Savannah-Northern Georgia Coastal	7,231,944	Savannah
Southern Georgia Coastal	1,059,104	Brunswick
Northern Florida Atlantic Coast	12,767,491	Jacksonville
Cape Canaveral	1,998,560	Cape Canaveral
Southern Florida Atlantic Coast	13,664,332	Port Everglades Harbor

Source: U.S. Army Corps of Engineers, 1972 Part 1.

10 starts at Jacksonville, Florida and continues westward to New Orleans and points beyond.

Additional Interstate Beltway loops encircle the cities of Boston, New York City, Philadelphia, Trenton, Baltimore and Washington, D.C. New York City in particular has a labyrinth of Interstate routes connecting and crossing the metropolitan region.

Railroad System

Freight lines connect Portland, Maine, with northern and central Maine, Canada, and Boston, Massachusetts. Additional freight service is provided from Boston to Buffalo, New York City, New Hampshire, Vermont and western Massachusetts. Major freight lines connect New York City with points north, west and south. Baltimore as well as the Hampton Roads area, ports of North and South Carolina and Georgia are connected with Atlanta, Jacksonville, Miami, and points inland.

Aviation Routes

The major airport in the New England area is Boston's Logan International, which is located immediately on the coastal zone. Additional smaller airports are located in Portland and Augusta, Maine, and Portsmouth, New Hampshire. Providence's Theodore Greene Airport provides commerical service to most of the Lower New England area. However, airports at New London, New Haven and the other lower Connecticut urban areas provide private air service to this portion of the Atlantic coast region. The Greater New York City Metropolitan area is provided with commercial and extensive air freight services by three airports: John F. Kennedy International, Laguardia, and Newark. Philadelphia is served by two airports, and the Baltimore-Washington, D.C. corridor is served by three airports: Baltimore-Washington International, Dulles International, and National Airport. Richmond and Norfolk, Virginia and points south in North and South Carolina (Wilmington, Myrtle Beach, Charleston and Savannah) are provided with commercial air service. The major Florida Atlantic coast area airports are located at Jacksonville, Orlando, Fort Lauderdale, Palm Beach and Miami.

(8) Historical and Projected Economic Growth in the Atlantic Coast Region

The information presented in this section is drawn in part from Chapter 12 of the Coastal and Offshore Environmental Inventory: Cape Hatteras to Nantucket Shoals, Complement Volume, Marine Publication No. 3, University of Rhode Island (URI), and from a study provided to BLM by Planners Incorporated, Washington, D.C. The data has been revised using the latest OBERS data from the Bureau of Economic Analysis (BEA), U.S. Department of Commerce, Washington, D.C.

North and Mid-Atlantic Region

Economic activity in the North and Mid-Atlantic region is a dominant force in the national economy of the Nation by nearly every measure, even though it has been growing more slowly than the Nation as a whole. About 24 percent of all employed persons in the United States in 1970 worked in the Northeast Coastal BEA Economic Areas, and 26 percent of the total personal income generated in the U.S. in that year was also in these areas.

Table 26 Population, Employment and Income by Regions and U.S., 1970

		Northeast Region		
	Total U.S.	No. Atlantic	Mid-Atlantic	So. Atlanti
Total Population	203,857,864	10,394,541	35,786,629	5,713,391
% of U.S.	---	5.1	17.6	2.8
Total Employment	79,306,527	4,293,184	14,536,763	2,189,312
% of U.S.	---	5.4	18.3	2.8
Total Personal Income*	$708,583,931	$38,606,566	$144,889,903	$18,320,765
% of U.S.	---	5.4	20.4	2.6

* Total personal income in thousands of 1967 dollars.

Source: 1972-E OBERS Bureau of Economic Areas, U.S. Department of Commerce.

The most important economic activities in the North and Mid-Atlantic region are manufacturing, finance and service indistries, and the Federal Government. In contrast, extractive industries (mining, agriculture, forestry and fisheries) play a relatively small role in the regional economy. The relative importance of population-related activities such as trade, transportation, construction, and State and local government is nearly the same in this region as in the Nation as a whole.

The following table shows earnings data for industries and their relative regional importance for the Atlantic Coast region in 1970.

The Northeast is presently growing at a slower rate than it did in the previous two decades as measured by population and employment. As an older and more mature region with a broad industrial base, its original leading position is being gradually eroded by other regions of the Nation currently undergoing a period of substantive growth.

The University of Rhode Island (URI) Report assessed the future general outlook for the Northeast:

> "While employment in the NAR (North Atlantic Region) is expected to grow at a rate commensurate with population, it will exhibit a continuing shift in composition--fewer production jobs in the manufacturing sector and more white collar and service jobs in office buildings. The distribution of new employment growth among belts in the region is expected to follow the pattern of population change, although manufacturing activity is likely to continue its shift from central cities to suburbs, reflecting the need for greater amounts of less expensive land, the continued elaboration of the highway network and a decreasing dependence on the coastal railroads as a transportation system. Finally, agriculture, forestry, fishing, and mining are projected to decrease in relative (and, in some cases absolute) importance as land values are pushed upward by the spread of urbanization and industrialization. However, an element of uncertainty exists here: the crisis in power for instance, could introduce new vigor into the coal extraction industry, or the advent of controlled thermonuclear fusion could render it obsolete. Then, too, there are the untapped

Table 27 Total Earnings by Selected Industries, 1970
(in thousands of 1967 dollars)

		Northeast Region		
Industry	Total U.S.	No. Atlantic	Mid-Atlantic	So. Atlantic
Total Earnings	562,311,127	29,886,297	114,606,914	13,945,668
Agriculture, Forestry and Fisheries	19,640,721	293,967	1,284,168	633,292
% of Regional Total	3.5	1.0	1.1	4.5
Mining	5,647,503	20,949	161,457	31,917
% of Regional Total	1.0	0.1	0.1	0.2
Contract Construction	34,457,902	1,985,637	6,422,435	1,185,194
% of Regional Total	6.1	6.6	5.6	8.5
Manufacturing	156,291,100	9,428,230	28,260,449	2,206,572
% of Regional Total	27.8	31.5	24.7	15.8
Transportation, Communication and Public Utilities	39,925,053	1,756,760	8,753,714	1,184,363
% of Regional Total	7.1	5.9	7.6	8.5
Wholesale & Retail Trade	93,080,363	4,844,406	18,934,165	2,578,110
% of Regional Total	16.6	16.2	16.5	18.5
Finance, Insurance, and Real Estate	28,880,241	1,827,850	8,379,860	831,087
% of Regional Total	5.1	6.1	7.3	6.0
Services	85,077,671	5,123,781	20,222,485	2,492,843
% of Regional Total	15.1	17.1	17.6	17.9
Government	99,310,475	4,550,157	22,562,234	2,802,319
% of Regional Total	17.6	15.2	19.7	20.1

Note: Percents may not total to 100 due to rounding.

Source: 1972-E OBERS Projections (Volume 5), U.S. Department of Commerce.

> mineral reserves of the continental shelf, ... whose exploitation depends on the political resolution of opposing pressures of economics and environmental protection."

South Atlantic Region

The coastal areas of the South Atlantic region from Cape Hatteras to Cape Canaveral have in the past several decades constituted a generally depressed area with a major need for economic development and new employment opportunities. This entire region accounted for 2.8 percent of the U.S. population and employment in 1970, but only 2.6 percent of the total personal income.

Per capita income was below the U.S. average in this region in 1970, and was less than three-fourth's of the U.S. per capita income. Poverty was unusually high for non-whites, and there is a close correlation between low income, depressed counties and the percentage of non-white persons living in the county. Earnings levels are lower for minorities and females, and opportunities in this region are more limited for both.

However, aggregate income growth, the best indicator of economic development, has been increasing in most counties within the region more rapidly than the U.S. average in recent years.

According to 1970 Bureau of the Census data, three-fourths of the population within this region is concentrated in seven Standard Metropolitan Statistical Areas (SMSA's): Jacksonville, Charleston, Melbourne-Titusville-Cocoa Beach, Savannah, Wilmington, Daytona Beach, and Miami-Palm Beach. At a growth rate of one percent per year, the population of the thirty-county area, as defined by the Bureau of Economic Analysis Economic Area, will reach nearly 3,000,000 by the year 2000.

Farm income within this region is declining with time, in large part due to the greater number of smaller less economic farm units and poor soils. Farm employment is decreasing approximately 7 percent annually. Farm-derived income is now high only in six counties.

Mining and forestry are minor occupations in relation to other activities.

The five major manufacturing centers, in order of importance, are the Jacksonville SMSA, Brevard SMSA, Savannah SMSA, Charleston SMSA, and the Wilmington SMSA. The dominance of manufacturing in comparison with the U.S. average is highest in the Wilmington SMSA, followed by the counties of Glynn, Georgia; Georgetown, Beaufort and Colleton, South

Carolina. The annual growth rate of manufacturing income exceeded the U.S. average by more than one percent annually in all of the above counties except Brevard, where it fell sharply, and in Savannah. With these two exceptions, these areas are the industrial growth centers of the region.

Population in the South Atlantic region is projected to increase at a rate two and a half times that of the U.S. rate. Employment is projected to increase by almost three times that of the U.S. average as a whole (Table 28). Thus, the South Atlantic region, although economically depressed in past decades, is currently undergoing considerable growth that is projected to continue in the future.

(9) Commercial Fisheries in the Atlantic Coast Region

The following section presents data on the commercial fisheries industry of the Atlantic states. Included are data for total volume and value of fishery landings, important species landed, number of fisherman, value of processed fish products, and the number of processing and wholesaling establishments and their employment. Data for total volume and value of fish landings are available for 1973; detailed breakdowns of catch by species, however, are available only through 1971. The information is taken from the National Marine Fisheries Service (U.S. Department of Commerce) publications of current fisheries statistics, and reflects commercial activity in both nearshore and offshore areas.

Table 28

Regional Population and Employment
(1972-E, OBERS, Bureau of Economic Analysis)

Region	1950	1970	Percent Change 1950 to 1970	1990	Percent Change 1970 to 1990
North Atlantic BEA Areas 001, 002, 004, 005					
Population	8,216,435	10,394,541	26.5	12,348,100	18.8
Employment	3,234,329	4,293,184	32.7	5,645,700	31.5
Middle Atlantic BEA Areas 014, 015, 017, 018, 021, 022, 023, 024					
Population	26,678,797	35,786,629	34.1	43,319,600	21.0
Employment	10,819,592	14,536,763	34.4	19,658,500	35.2
South Atlantic BEA Areas 030, 031, 033, 034, 035, 036					
Population	2,817,341	5,713,391	102.8	8,628,200	51.0
Employment	1,044,950	2,189,312	109.5	4,343,300	98.4
United States - Total					
Population	151,236,648	203,857,864	34.8	246,039,000	20.7
Employment	57,474,912	79,306,527	38.0	106,388,000	34.1

Table 29 Total Volume and Value of Fish Landings, By State

State	1973 Volume (1,000 lbs.)	1973 Value ($ 1,000)	1971 Volume (1,000 lbs.)	1971 Value ($ 1,000)
Maine	143,300	43,100	98,000	4,500
New Hampshire	1,400	900	488	81
Massachusetts	269,000	57,400	253,000	28,300
Rhode Island	105,000	15,100	77,000	5,100
Connecticut	4,800	1,300	5,000	498
New York	36,600	22,000	20,200	2,600
New Jersey	209,800	18,400	80,500	4,000
Delaware	10,300	2,000	432	92
Maryland	67,000	20,700	16,200	1,700
Virginia	631,400	39,400	427,100	9,300
North Carolina	137,900	16,100	119,200	4,400
South Carolina	21,100	11,300	4,700	536
Georgia	17,200	10,600	974	260
Florida, East Coast*	n.a.	n.a.	54,700	7,200

n.a. -- not available

Table 30 Number of Fishermen, by State, by Type, 1971

State	Vessel	Boat and Shore	Casual
Maine	486	5,414	5,980
New Hampshire	0	87	478
Massachusetts	2,349	1,386	4,231
Rhode Island	696	390	928
Connecticut	63	188	550
New York	552	1,706	2,953
New Jersey	1,083	692	905
Delaware	92	101	521
Maryland	1,527	4,474	7,927
Virginia	2,627	1,370	951
North Carolina	1,725	1,075	1,360
South Carolina	795	240	487
Georgia	885	211	453
Florida, East Coast*	1,159	1,288	502

* The Florida East Coast includes the coastal counties from Nassau to Dade.

Table 31 Commercial Fisheries on the Atlantic Coast, 1971

State	Fishery	Importance (% of total catch by weight)		Importance (% of total catch by value)		Shellfish Catch (Millions of Pounds)	Shellfish Value (Millions of Dollars)
		Finfish	Shellfish	Finfish	Shellfish		
Maine	Ocean perch	47.5		51.1			
	Sea herring	29.2		15.3			
	Whiting	10.1		10.6			
	Shrimp		41.1		14.3		
	American lobster		39.4		65.8		
	All Shellfish					44.7	26.6
New Hampshire	All shellfish					0.85	0.78
Massachusetts	Flounders	27.2		40.6			
	Cod	18.4		20.1			
	Sea herring	17.1					
	Haddock			18.7			
	American lobster		25.8		34.5		
	Shrimp		25.4				
	Scallops		25.4		46.5		
	All Shellfish					23.6	20.0
Rhode Island	Menhaden	24.9					
	Flounders	24.7		51.0			
	American lobster		59.3		81.0		
	Clams		30.8				
	All Shellfish					9.1	7.4
Connecticut	All Shellfish					1.7	1.2
New York	Flounders	50.0		36.4			
	Scup/porgy	6.4		15.5			
	Clams		76.5		70.0		
	All Shellfish					16.2	16.0

Table 31 (cont.)

State	Fishery	Importance (% of total catch by weight) Finfish	Importance (% of total catch by weight) Shellfish	Importance (% of total catch by value) Finfish	Importance (% of total catch by value) Shellfish	Shellfish Catch (Millions of Pounds)	Shellfish Value (Millions of Dollars)
New Jersey	Menhaden	75.3		25.0			
	Flounders	4.1		19.3			
	Crabs		89.0	69	69.0		
	All Shellfish					35.1	8.1
Delaware	Clams		84.7		68.7		
	All Shellfish					9.2	1.6
Maryland	Menhaden	36.4					
	Alewives	17.3					
	Striped bass	16.7					
	Crabs		46.9		17.9		
	Oysters		29.0		58.7		
	Clams		23.9		23.5		
	All Shellfish					58.9	17.9
Virginia	Menhaden	92.3		68.8			
	Crabs		75.0		32.0		
	Oysters		13.0		44.0		
	All Shellfish					58.9	17.9
North Carolina	Menhaden	66.7		25.0			
	Alewives	10.6					
	Flounders			25.0			
	Crabs		59.9		16.2		
	Shrimp		31.4		70.6		
	All Shellfish					24.2	6.8

Table 31 (cont.)

State	Fishery	Importance (% of total catch by weight) Finfish	Shellfish	Importance (% of total catch by value) Finfish	Shellfish	Shellfish Catch (Millions of Pounds	Shellfish Value (Millions of Dollars)
South Carolina	Spot	26.0					
	Catfish/bullheads	19.2		26.9			
	Alewives	15.0					
	Sea bass			24.6			
	Shrimp		55.1		84.0		
	Crabs		38.7				
	All Shellfish					19.4	7.6
Georgia	Shad	43.0		51.0			
	Shrimp		51.1		89.6		
	Crabs		48.3				
	All Shellfish					17.4	7.2
Florida (East Coast)	Menhaden	36.2					
	Catfish/bullheads	29.8		47.2			
	King mackeral			11.4			
	Crabs		53.2				
	Shrimp		22.9		42.9		
	Spiny lobsters		19.6		37.7		
	All Shellfish					17.3	7.7

Table 32 Processed Fisheries Industry on the Atlantic Coast, 1971

State	Value of Processed Products (Million $)	Number of Wholesaling and Processing Plants	Average Total Employment
Maine	54.8	242	3,229
New Hampshire	17.9	13	358
Massachusetts	173.2	212	4,777
Rhode Island	5.3	32	254
Connecticut	0.25	8	34
New York	56.9	219	2,332
New Jersey	52.8	108	1,887
Delaware	4.7	16	269
Maryland	68.1	207	3,735
Virginia	45.1	248	4,161
North Carolina	12.5	174	1,400
South Carolina	10.8	75	764
Georgia	36.6	51	1,814
Florida, East Coast *	38.3	143	1,518

* The East Coast of Florida includes the coastal counties from Nassau to Dade.

(10) Oil and Gas Resources, Atlantic Coast Region

The following estimates of oil and gas resources in coastal State waters are provided by the U.S. Geological Survey. USGS emphasizes that the estimates are speculative; only the maximum credible expectations are shown.

Table 33 Estimates of Undiscovered Recoverable Resources in Coastal State Waters*

(Oil in billion barrels; includes natural gas liquids)
(Gas in trillion cubic feet)

Area	Oil	Gas
North Atlantic	0-2	0-5
Middle Atlantic	0-2	0-5
South Atlantic	0-2	0-5

d. Existing Environmental Quality Problems in Coastal Zone

(1) Water Quality

Major centers of high population concentrations occur along the Atlantic coastline. Embayments along the coast receive large quantities of industrial, agricultural, and municipal wastes. Several factors impact upon the water quality as a result of these effluents. Flushing times of embayments and rivers influence the maximum acceptable pollutant loading in that pollutant levels are cumulative to varying degrees.

---

* On March 26, 1974, the U.S. Geological Survey released estimates of the undiscovered recoverable oil and gas resources for broad areas of the OCS. Those estimates were based on statistical parameters of oil occurrences that apply only to broad geographic areas. It is entirely inappropriate to apply the same parameters to small, specific areas. The resource figures in the above table represent a general estimate, based on the above referenced information of minimum and maximum volumes of oil and gas that might be recovered from the various OCS State areas. It is statistically unsound to add the maxima and minima for an exceptable range of resources for any larger area. New estimates have recently been prepared by the USGS for the undiscovered recoverable resources in OCS areas, and are discussed previously in the Description of the Proposed Action.

Seasonal rates of freshwater runoff are usually higher in winter and spring than in summer and fall. Water quality would thus be further degraded during these low-flow seasons if the quantities of pollutants added remained the same throughout the year. The types and quantities of industrial effluents are significant. Heavy metals are toxic and have extended residence times in the estuary; they are subject to resuspension when the substrate is disturbed. The degree of sewage treatment is also important in the effluent's effect on dissolved oxygen and other water quality parameters. The types of pesticides being used in the watershed have particular significance in governing water quality. Long-lived pesticides such as DDT and its metabolic derivatives DDD and DDE have proven extremely harmful to organisms associated with embayments and rivers. More recently developed pesticides such as Sevin (a carbamate) are biodegraded over short periods of time and do not pose as significant a problem as do longer-lived pesticides.

Thus, water quality varies with the type and amount of pollutants added to a specific estuary, and can vary between estuaries which are in the same region. Florida's Biscayne Bay receives significant levels of sewage. Periodic plankton blooms of the dinoflagellate Gymmodium (red tide organisms) normally occur under present pollutant levels. These blooms have been responsible for fish kills and effects ranging from general nuisance to public health hazards.

An extensive "Estuarine Pesticide Monitoring Program" (conducted by the Fish and Wildlife Service) is underway along the Atlantic coast. The objective of this effort is to monitor pesticide residue levels in fishes along the coast. DDT levels, which historically have caused significant problems in commercial fisheries, appear to be declining due to the partial ban on its agricultural use. The concentrations of all pesticides in tissues indicate that concentrations in the water were in the range of tens of parts per trillion along the southeastern region. DDT has been proven to have been concentrated in successive trophic levels, causing concern for health at the commercial fisheries level.

Table 34 lists rivers and coastal systems which presently are influenced by various pollutants. The vast Chesapeake Bay system is discussed separately below.

Table 34 Pollutants in Atlantic Coastal Waters

	Water Body or System	Type(s) of Pollutant	Reference
1)	Saint Johns River	Heavy metals	VIMS, 1974
2)	Savannah River	Sewage, industrial wastes	Stickney and Miller, 1973
3)	Charleston Harbor	High nutrient levels	VIMS, 1974
4)	Florida-North Carolina region	Aldrin, BHC, dieldrin, DDT, DDE, DDD, ondrin, heptochor, epoxide, metoxychor, mirex, toxaphene, chorodane in blue crab samples	Mahood, et al., 1970
5)	Delaware Bay below Trenton	Municipal and industrial effluents, coliform bacteria, oil scums, untreated sewage,	
6)	Coastal waters of the northern New Jersey	Phenols, oils, trace metals waste heat, solid wastes, (dredge spoils, fly ash, incineration residue, sewage sludge, construction rubble) liquid sanitary wastes	URI, 1974
7)	Moriches Bay	coliform bacteria	
8)	Long Island Sound	industrial effluent and sewage, thermal loading	URI, 1974

Table 34 Pollutants in Atlantic Coastal Waters (cont.)

	Water Body or System	Type(s) of Pollutant	Reference
9)	Coastal waters off Massachusetts	Industrial wastes and sewage.	URI, 1974
10)	Pawtuxet Basin, Rhode Island	low dissolved oxygen, high coliform counts, high turbidity levels, sewage and industrial wastes	TRIGOM, 1974
11)	Nanagansett Bay	Industrial wastes, heated waters, stormwater runoff oil pollution heavy metals	TRIGOM, 1974
12)	New Bedford Harbor (Massachusetts)	agricultural runoff and municipal sewage	
13)	Boston Harbor	oil pollution	TRIGOM, 1974
14)	Neponset River (Massachusetts)	urban runoffs, combined sewers, paper mill effluents	
15)	The Mystic Basin (Massachusetts)	Urban runoff, obnoxious odors, black oozes	TRIGOM, 1974
16)	Piscataqua River	industrial wastes, sewage	TRIGOM, 1974

Table 34 Pollutants in Atlantic Coastal Waters (cont.)

	Water Body or System	Type(s) of Pollutant	Reference
17)	Androscoggin River	floating bottom deposits, obnoxious odors	
18)	Kenebec River	untreated sewage, industrial effluents pulp and paper effluents, pulp and paper, raw sewage	

The Chesapeake Bay system is heavily loaded with pollutants, but appears to be capable of rapid assimilation. This geographical area is experiencing rapid population growth which is exceeding the capability of sewage treatment plants. The major concern for this embayment is more adequate effluent treatment. Currently 42,000 acres of shellfish beds are closed to commercial fishermen because of pollution loading. The James River is an extreme example of the effects of high pollutant levels. The City of Richmond, Virginia dumped 33% of its sewage (population 500,000 in 1967) into the river untreated. Hopewell and Hampton Road also added to the pollutant loading. Heavy plankton blooms are common in this river. Both nitrogen and phosphorus are normally present in excess of the ability of phytoplankton to utilize them in winter. Extensive closing of potentially productive shellfish beds have occurred in the Hampton Road area because of bacterial levels. The overall effect of these high nutrient values has been to alter the food web in favor of species more able to survive in polluted conditions. Red tides are common in the lower Chesapeake Bay and reach the nuisance level. Extensive fish kills because of these plankton blooms, however are not common (Brehmer, 1967).

Ocean Dumping of Wastes and Dredge Spoils

Various offshore sites along the Atlantic coast have been used for ocean disposal of dredge spoil or industrial, military and commercial wastes. Since passage of the 1972 Marine Protection, Research and Sanctuaries Act, ocean dumping is regulated through manditory permitting by the Environmental Protection Agency. Revised guidelines for issuance of these permits are now being prepared by that agency. EPA regulations apply to territorial (0-3 miles offshore) and contiguous (3-12 miles) waters; ocean disposal outside the 12-mile zone falls within the authority of an agreement reached at an International Convention on the Prevention of Marine Pollution by Dumping of Wastes held in 1972. This agreement became binding on the U.S. on March 22, 1974.

(2) Air Quality

Air quality is generally good along the Atlantic coastline. In the vicinity of cities and industrial complexes however, air quality can reach health hazard levels. The major factors affecting air quality and quantities of pollutants emitted, distance from point sources, and meteorological conditions. Extended periods of thermal inversions reduce the vertical mixing in the air column. Pollutants which are emitted during these periods are trapped at lower altitudes and may build to hazardous concentrations. Figure 69 depicts predicted occurrences of heavy pollution based upon observed weather conditions. Table 35 presents the present status of air quality control regions along the Atlantic coast.

Secondary standards (Table 36) for SO_2 have been waived for the duration of the energy shortages the region is now experiencing.

Offshore air quality is generally better than that over adjacent nearshore areas. Airborne contaminants over Atlantic shelf waters are derived mainly from East Coast urban and industrial areas with lesser amounts contributed from more distant land areas (e.g. dust from the Sahara Desert) and local offshore point sources--ships and airplanes.

(3) Dredging

Major dredging efforts are underway along the Atlantic coastline. The major goals of most of these activities are replinishment of beach sands and deepening and widening of navigable channels. Other less important objectives include land fill and recreational boat harbor maintenance. For a more expanded discussion of the impacts of these actions on water quality, refer to the section on impacts.

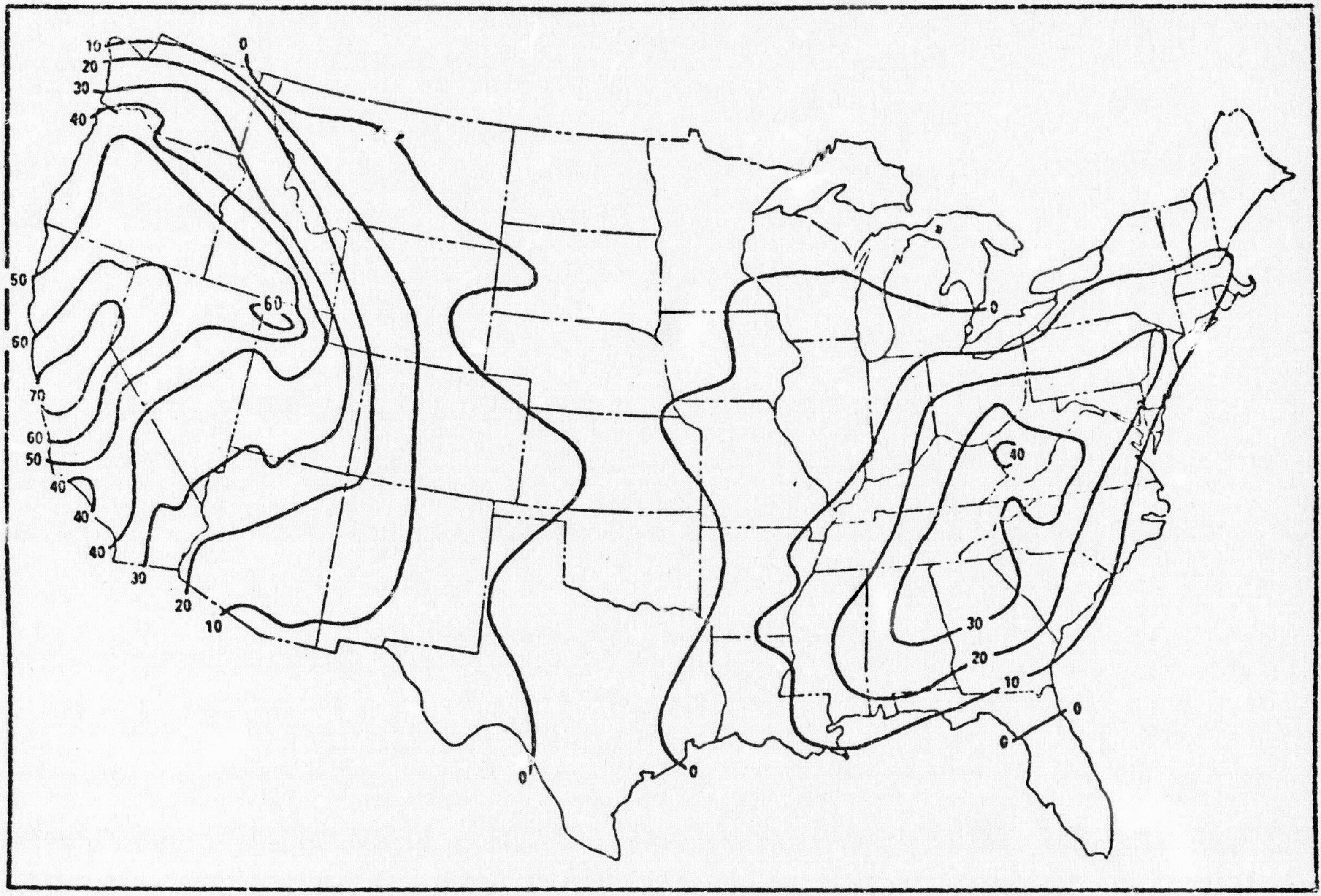

10
20
30
40
0
50
60
60
70
60
50
40
40
40
30
20
10
0
0
0
40
30
20
10
0
0

Figure 69. Isopleths of total number of forecast-days of high meteorological potential for air pollution in a 5-year period. Data are based on forecasts issued since the program began, August 1, 1960, and October 1, 1963 for eastern and western parts of the United States, respectively, through April 3, 1970. (After Holzworth, 1972).

TABLE 35.

A SAMPLE OF COASTAL AIR QUALITY CONTROL REGIONS BY CATEGORY FOR THREE TYPES OF POLLUTANTS

Air Quality Control Region	Category by Type of Pollutant*		
	SO_2	NOx	HC
Connecticut:			
Hartford, New Haven, Springfield Interstate, AQCR No. 42	I	I	I
Eastern Connecticut Intrastate, AQCR No. 41	II	III	III
Delaware:			
Southern Delaware Intrastate, AQCR No. 46	III	III	III
Florida:			
Jacksonville, Brunswick Interstate, AQCR No. 49	I	II	III
Central Florida Intrastate. AQCR No. 48	II	III	III
Southeast Florida Intrastate, AQCR No. 50	II	III	I
New Jersey:			
New Jersey Intrastate (Ocean, Atlantic, Cumberland, and Cape May Counties), AQCR No. 150	III	I	III
South Carolina:			
Charleston Intrastate, AQCR No. 199	I	I	III
Savannah Beaufort Interstate, AQCR No. 58	I	I	III
Virginia:			
Hampton Roads Intrastate, AQCR No. 223	I	II	I
Northeastern Virginia Interstate, AQCR No. 225	I	III	I

Source: Unpublished EPA data.

* Category I: Air quality does not meet primary standards.
Category II: Air quality meets primary standards.
Category III: Air quality meets secondary standards.

TABLE 36.

NATIONAL AIR QUALITY STANDARDS

Parameter	Standard [a] Primary	Standard [a] Secondary
Particulates		
Annual Geometric Mean	75 ug/m^3	60 ug/m^3
24-hour average	260 ug/m^3	150 ug/m^3
Sulfur Dioxide (SO_2)		
Annual Arithmetic Mean	80 ug/m^3 .03 ppm	60 ug/m^3 [b] .02 ppm[b]
24-hour average	365 ug/m^3 .14 ppm	260 ug/m^3 .1 ppm[b]
3-hour average	na	1300 ug/m^3 [b]
Nitrogen Dioxide (NO_2)		
Annual Arithmetic Mean	100 ug/m^3	100 ug/m^3
Carbon Monoxide (CO)		
8-hour average	10 mg/m^3 9 ppm	10 mg/m^3 9 ppm
1-hour average	40 mg/m^3 35 ppm	40 mg/m^3 35 ppm
Hydrocarbons		
3-hour average	160 ug/m^3	160 ug/m^3
6-9 A.M. average	.24 ppm	.24 ppm
Photochemical Oxidants		
1-hour average	160 ug/m^3 .08 ppm	160 ug/m^3 .08 ppm

---

[a] Standards quoted are maximum values. Primary standards are "health" related, secondary are "welfare" related. The standards, except for annual averages, may be exceeded only once per year per monitoring site. Annual averages may never be exceeded.

[b] Secondary standards for SO_2 have been temporarily revoked due to the "energy crisis" (personal communication, EPA, April, 1974 from TRIGOM, 1974)

SOURCE: The Federal Register, November, 1971.

B. Description of Nearshore and Coastal Zone Management

2. Gulf of Mexico Region (and Sub-Areas)

a. Geology

The geology of the nearshore and coastal zone has been described previously in the discussion of the offshore environment (section II.A.2.a.) since unlike biological and some other physical parameters, geologic structures are not commonly distinguished according to an arbitrary division based on water depth or proximity to the shoreline. Where specific geologic structures are unique to a nearshore area, they are noted as such.

b. The Biological Environment and Communities of the Coastal Zone

The area under consideration here is the band of coastal lands and waters from the tidal zone landward to the level of 20 feet above MSL (mean sea level), or roughly thirty miles inland and extending along the northern Gulf of Mexico from the southern end of Florida to the Rio Grande at the Texas-Mexico border. Also treated are the embayments and barrier islands.

The direct distance along this coastline is approximately 1600 miles; however, the circuitous route of coastline through the bays and estuaries is estimated to be at least 10 times this distance. The paramount feature of the Gulf coast is the Mississippi River Delta and its associated seven million or more acres of marsh and estuaries. The Mississippi watershed covers about one-third of the United States, and the resultant freshwater discharge is responsible for the major saltwater dilutions within the central Gulf coast region. The Mississippi contributes most of the nutrients to the estuaries of Louisiana - the most extensive in the Gulf - which supports the third largest shrimp production and the second largest oyster production in the United States (U.S. Dept. of Commerce, 1974).

East of the Mississippi Delta, the proportion of estuaries to the coastal zone diminishes and becomes more commonly characterized by high energy sand beaches. The wetlands which are present are extremely valuable in terms of biological productivity.

Along the northwest Gulf coast, the marshlands diminish rapidly into a narrow band along the coast, and are nearly absent in the semiarid regions of South Texas. A significant portion of the coastal zone, however, is composed of a vast system of bays and lagoons which are engendered for the most part by the extensive system of barrier islands.

(1) Salt Marsh

Most salt marshes exhibit distinct zonation by the most abundant plants. This zonation is controlled by a variety of factors including soil types, soil salinity, tide, elevation, drainage characteristics and pH. The extent of saline intrusion into the marsh depends to a large degree on the rate of percolation (movement through soils) of saltwater at high tide (Jackson, 1952), and the location of points of influx of freshwater from the mainland.

In the vicinity of the Mississippi Delta, the saline marsh is generally adjacent to the beach rim and may vary from 1 to 15 miles in width. The saline marsh merges with the broad band of brackish marsh which is further removed from the sea rim and vegetated by wire grass, coco, and three-cornered grass.

The comparatively small number of plant species of the saltmarsh limits the number of available niches in which organisms may live. Chabreck (1972) recorded only 17 plant species present in the coastal saltmarsh of Louisiana, with saltmarsh cordgrass (*Spartina alterniflora*) being the dominant species. However, with the inland marsh succession, habitat complexity increases significantly. The same author noted 93 plant species present in the fresh marsh.

While there may be small regional differences in composition within the saltmarshes of the Central Gulf, these data represent general composition.

The dominant plant, cordgrass, is most densely distributed along the seaward side of the marsh. Of all marsh species, cordgrass is best able to endure the longest and deepest inundation by saltwater (Humm, 1973). Other grasses include Blackrush (*Juncus roemerianus*), saltgrass (Distichlis spicata), and Batesgrass (*Batis maritima*).

Since much marsh productivity goes to nourishing other ecosystems, the numbers of resident animals which depend on this ecosystem for their entire livelihood are also limited. Resident salt marsh species include primarily the furbearing muskrat, nutria, raccoon and otter, wading birds and reptiles and amphibians. Because of the nutrient turnover these marshes provide, they also rate high in value for wintering waterfowl.

(2) Brackish Marsh

Brackish marshes are usually situated between the seaward salt marsh and landward intermediate and fresher marshes. In the Gulf of Mexico region, these brackish marshes are primarily located in southern Texas, southwestern Louisiana and along the west coast of Florida.

Salinities vary annually between an average low of 3.4 ppt to an average high of 16.7 ppt. Highest salinities occur in June, or in the drought periods (Palmisano, 1971).

Plant species diversity increases as one approaches the upland environment from the marsh. Forty species of plants (Chabreck, 1970) have been recorded in the brackish marsh. The dominant species include wiregrass, Spartina patens, and saltgrass, Distichlis spicata.

The coastal zone of the northern Gulf of Mexico provides some of the best, if not the "premier", waterfowl wintering habitat in North America (Gusey and Maturgo, 1973). Of this total area, the coastal marshes of Louisiana and the rice area of southwest Louisiana constitute the largest general waterfowl wintering area within the United States. However, not all of the coastal marsh zone is suitable for waterfowl. Since most waterfowl food plants are confined to fresh and brackish-water marshes, and to fresh water ponds throughout the area, waterfowl tend strongly to concentrate in these areas. There is little evidence that the more saline marshes are used by waterfowl to any extent. Throughout the coastal marsh area, food and water conditions are highly variable, and waterfowl concentrations shift frequently from one area to another. Consequently, waterfowl do not generally winter throughout the entire coastal marsh area, and may be totally absent from some areas throughout the winter.

Great fluctuations in Gulf coast waterfowl habitat characterize these marshes. Hurricanes, marsh fires, erosion, subsidence, silt deposition, animal populations, and human activities are but a few of the factors that cause constant change in the waterfowl habitat of coastal Louisiana. Levees and canals have had an adverse effect; nevertheless, the coastal marshes continue to demonstrate an exceptionally high carrying capacity by holding more than 2/3 of the total wintering population in the Mississippi Flyway. In 1968, the Mississippi Flyway contained more than 1/3 of the U.S. population of wintering waterfowl.

(3) Intermediate Marsh

Intermediate marshes extend further inland than brackish marshes. In the Gulf of Mexico coastal zone they are distributed predominantly in the southwestern region of Louisiana and southeastern Texas.

A more diverse vegetation occurs in the intermediate marsh than the brackish or saline marshes. Based on the data given by Chabreck (1970), fifty-four species of plants or 35% more than in the brackish zone occur in the intermediate marshes. The dominant wiregrass makes up a third of the vegetation. Roseau, *Phragmites cummunis*, and bulltongue, *Sagittaria falcata*, also occur here.

The intermediate marsh is heavily colonized by mammalian fur bearers. Natural plant distribution has been significantly altered in much of the marsh because of the fur mammal management practices of man. Much of the marsh has been burned, or burned and sodded to provide stands of three-cornered grass and other muskrat foods.

(4) Freshwater Marsh

The only freshwater marsh in the area of interest is situated in the more central region of the Mississippi Delta near the distributary passes. Major species of vegetation in this marsh are: roseau cane, Eurasian water milfoil, alligator weed, duck weed, water hyacinth, dogtooth grass, bulltongue and pondweed (Stone, 1972).

(5) Mangrove Swamp

The three common mangroves in the order of their abundance are the red mangrove, the black mangrove and the buttonwood, and their zonation landward is in that order. A fourth and less abundant species, the white mangrove, generally grows landward of the black mangrove. Their distribution is world-wide on tropical and subtropical shores of oceans and estuaries. However, their distribution in the Gulf states is limited principally to Florida, but small populations do exist on some of the barrier islands off the Louisiana coast.

Mangroves grow on peat, muck, marl, sand, or rock, and such environmental factors as killing frost and land elevation control their distribution. Their seedlings germinate while attached to the parent tree; seedlings detach and float in the sea, where they remain alive several months, allowing them to be carried long distances by currents.

As with salt marshes, mangrove stands serve as a transitional buffer zone between stretches of low-energy coastal waters and uplands. They afford greater protection from storms and hurricanes than broad salt marshes, not only against wave action and high water but also against winds. Mangroves are active land-builders as well as lowland protectors. Debris that accumulates in their tangle of prop roots is partly converted into peat upon which they grow.

Mangrove stands are a habitat for many species of marine algae that attach to their prop roots, along with a host of both sessile and freeliving invertebrates. A variety of birds are characteristic of mangroves, some of which produce rookeries on the islands, but very few animals are restricted to mangrove stands.

(6) Barrier Islands

Several groups of barrier islands front the coastal states of the Gulf of Mexico. Many offer environments distinct from the other island groups. The following narrative describes representative islands for different regions of the Gulf.

The Texas coastal area is fronted by a 300 mile long chain of barrier islands and peninsulas. The most prominent of these in terms of length is Padre Island which extends from Brownsville to Corpus Christi. The vegetative communities on this island differ somewhat from those on the mainland principally in density and woody species. Padre Island is also a rather severe environment for mammals, reptiles and amphibians since high summer temperatures, strong winds and occasional droughts are not infrequent. Nevertheless, viable faunal communities consisting of birds, mammals, reptiles and amphibians do thrive in the area.

The island today is a grassland with seacoast bluestem and seashore dropseed dominating the foredunes with sea oats and railroad vine occupying the dune surfaces. An assortment of other grasses and forbes are also intermixed with the above species. Higginbotham (1972) estimated that about 61 per cent of the island was low coastal sands with seacoast bluestem and gulfdune paspalum being the dominant vegetation. Wildlife species associated with the island vegetative type consist principally of xeric (dry environment) species of small mammals and reptiles. Predators (coyotes, badgers, etc.) are also normal participants in the community.

Salt marshes occur sparsely on the landward side of the island. These occur mainly as poorly drained shallow depressions at or slightly above sea level. Vegetation is represented by species of cordgrasses, flatsedges and rushes with several species of aquatic forbes intermixed. Wildlife use consists of winter utilization by waterfowl, seasonal occurrences of shore and wading birds and aquatically-oriented reptiles.

Terrestrially-oriented wildlife associated directly with the beach environment of Padre Island is almost totally dominated by several species of shore and wading birds. The beach provides the bulk of the food supply for these birds as food organisms are washed ashore by wave and tidal action. Several predacious birds also utilize this environment, searching for food in the shallow waters adjacent to the beach.

Marine turtles are totally dependent on beach habitat for nesting activities. Three of the sea turtles (Leatherback, hawksbill and Ridley) in the Gulf of Mexico are classified as endangered. However, their occurrence on Padre Island is incidental and recent nesting attempts have not been verified.

There are three prominent groups of barrier islands along the Louisiana coast: (1) the Chandeleur Islands, (2) Grand Isle and

Grande Terre Isle, and (3) Isles Derniere and the Timbalier Islands.

The flora of these islands is a microcosm of the Louisiana marshlands. Beach and dunes, fresh and salt marsh, sand flats and interior plant association are all represented. Table 37 lists flora and fauna common to these barrier islands.

Table 37 Flora and Fauna of Barrier Islands Off Louisiana.

Flora - cordgrass (Spartina), saltgrass, three square, morning glories, sea ox-eye, love grass, sea pine, lippia, croton.

Fauna - Herons, egrets, gulls, terns, numerous shorebirds, fox, raccoon, rabbits, nutria, rats.

(7) Seagrasses

Seagrasses consist of species of flowering plants that grow completely submerged (some are tidally emergent) in brackish to saline waters. They are limited to waters where sunlight penetration permits photosynthesis, such as are found in the shallow waters of bays and around islands in areas of low turbidity.

Marine grass beds support one of the highest biomass densities in the marine environment, for they not only provide a valuable food source for migratory waterfowl and shorebirds, but are also prime nursery grounds for shrimp, crabs and fishes of all types. While few animals feed on the grasses, many feed on organisms which attach to or live on them, viz., snails and mussels. Additionally, seagrass detritus provides material for a more basic food web.

Seagrass communities are fragile ecosystems which advance and decline in response to minor changes in water quality, turbidity, or sediment loads and are vunerable to storm damage. They are therefore difficult to quantify and chart with accuracy on a regional basis (U. S. Army Corps of Engineers, 1973).

The Mississippi River interrupts an otherwise continuous band of seagrasses which extend along the Gulf Coast from Florida to Texas. The turbid fresh water of the river adversely affects inshore seagrass beds as far southwest as Galveston, Texas (Humm, 1973). Of the 647 plant species recorded in the Gulf of Mexico, 329 occur from the shore to 10-meter depth (Earle, 1972). The most common species include turtlegrass, manateegrass, shoalgrass, and widgeongrass. The latter species is found in the less saline waters of the coastal inlets and bays.

The environmental role of seagrass has been thoroughly outlined by Humm (1973) as follows:

(1) They serve as a sediment trap, stabilizing bottom sediments from the water's edge to a depth of 6 to 16 meters or more.

(2) They carry on primary productivity that may considerably exceed that of benthic algae or phytoplankton in the same area.

(3) They serve as a direct food source for a few animals, including sea urchins, sea turtles, manatees, and certain herbivorous fishes; partially decomposed leaves in the form of detritus serve as a food for a wide variety of detritus-feeders, especially invertebrates but also some fishes.

(4) They serve as a refuge, and a source of food organisms as well, for juveniles of many species of seafood organisms including shrimp, crabs, bay scallops and fishes.

(5) They provide a habitat for a certain assemblage of invertebrate species that burrow or grow attached to the leaves; these organisms might otherwise be uncommon or absent in habitat that lack seagrasses.

(6) They provide an important substrate for attachment of scores of species and a significant biomass of benthic algae that otherwise would be rare or absent in an area.

In areas where seagrasses have been removed, the habitat rapidly declines from a fertile environment to a virtual desert (Wood et al., 1969).

(8) Estuaries and Embayments

The estuarine waters of the northern Gulf coast, from the Texas-Mexico border to the tip of the Florida peninsula, cover an area in excess of 6 million acres. More than 60% of this acreage is located along the Louisiana-Mississippi coast. The importance of estuaries to the viability and survival of coastal flora and fauna has repeatedly been emphasized by numerous spokesmen and authors from the scientific community. In general, the estuaries and bays of the Gulf coast support, either directly or indirectly, nearly one-third of the U. S. fisheries (U. S. Dept. of Commerce, 1974).

Estuaries and bays are highly productive ecosystems. They receive nutrients from upland areas via major river systems, especially during spring flooding. They also receive the nutrient wash-out from tidal flushing of the salt marsh, particularly in mid-winter when marsh grass of the previous season is decomposing. The dynamics of this system holds for the estuarine areas of the central and eastern Gulf. Diagrammatic cross sections including a listing of representative invertebrate species are shown in Figures 70 and 71 (Collard and D'Asaro, 1973). Figure 70 typifies the region from Louisiana to Cedar Key, Florida, although many of the species listed may be found at significant distances west of Louisiana and south of Cedar Key. Figure 71 summarizes the fauna found in bays in the southeastern

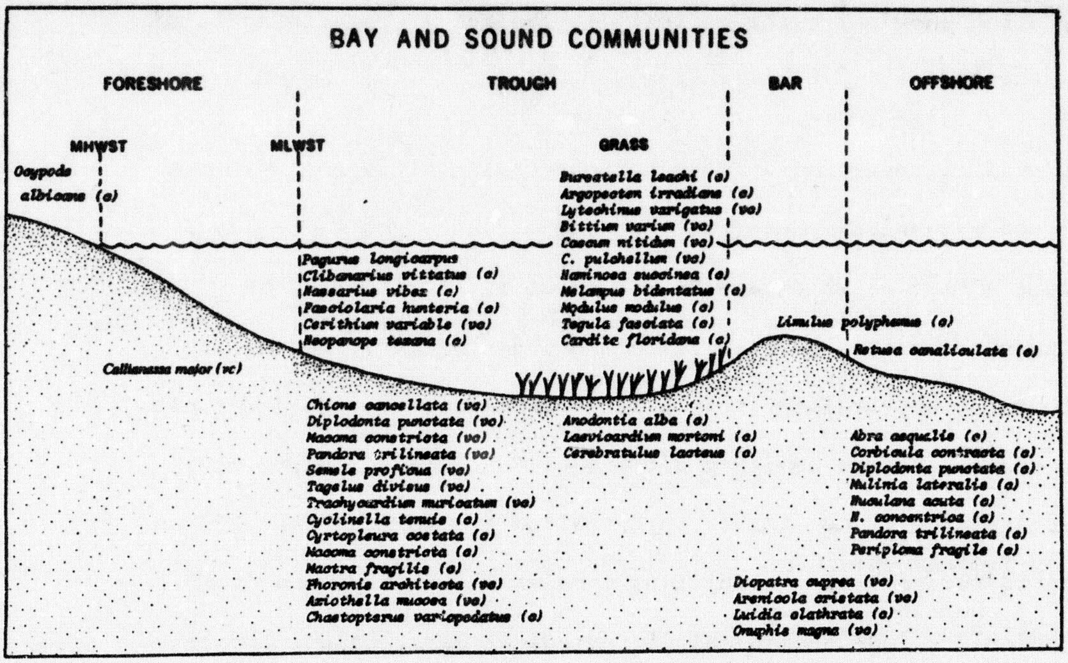

BAY AND SOUND COMMUNITIES
FORESHORE
TROUGH
BAR
OFFSHORE
MHWST
MLWST
GRASS
Ocypode albicans (c)
Bursatella leachi (c)
Argopecten irradians (c)
Lytechinus varigatus (vc)
Bittium varium (vc)
Caecum nitidum (vc)
C. pulchellum (vc)
Haminoea succinea (c)
Melampus bidentatus (c)
Modulus modulus (c)
Tegula fasciata (c)
Cardita floridana (c)
Pagurus longicarpus
Clibanarius vittatus (c)
Nassarius vibex (c)
Fasciolaria hunteria (c)
Cerithium variable (vc)
Neopanope texana (c)
Limulus polyphemus (c)
Retusa canaliculata (c)
Callianassa major (vc)
Chione cancellata (vc)
Diplodonta punctata (vc)
Macoma constricta (vc)
Pandora trilineata (vc)
Semele proficua (vc)
Tagelus divisus (vc)
Trachycardium muricatum (vc)
Cyclinella tenuis (c)
Cyrtopleura costata (c)
Macoma constricta (c)
Mactra fragilis (c)
Phoronis architecta (vc)
Axiothella mucosa (vc)
Chaetopterus variopedatus (c)
Anodontia alba (c)
Laevicardium mortoni (c)
Cerebratulus lacteus (c)
Abra aequalis (c)
Corbicula contracta (c)
Diplodonta punctata (c)
Mulinia lateralis (c)
Nuculana acuta (c)
N. concentrica (c)
Pandora trilineata (c)
Periploma fragile (c)
Diopatra cuprea (vc)
Arenicola cristata (vc)
Luidia clathrata (c)
Onuphis magna (vc)

Figure 70 Bay and sound communities: Carolinian affinities. Most species listed are wide ranging, occurring in sand and grass. Typical of northern Gulf Coast from Louisiana to Cedar Key, Florida (from Collard and D'Asaro, 1973).

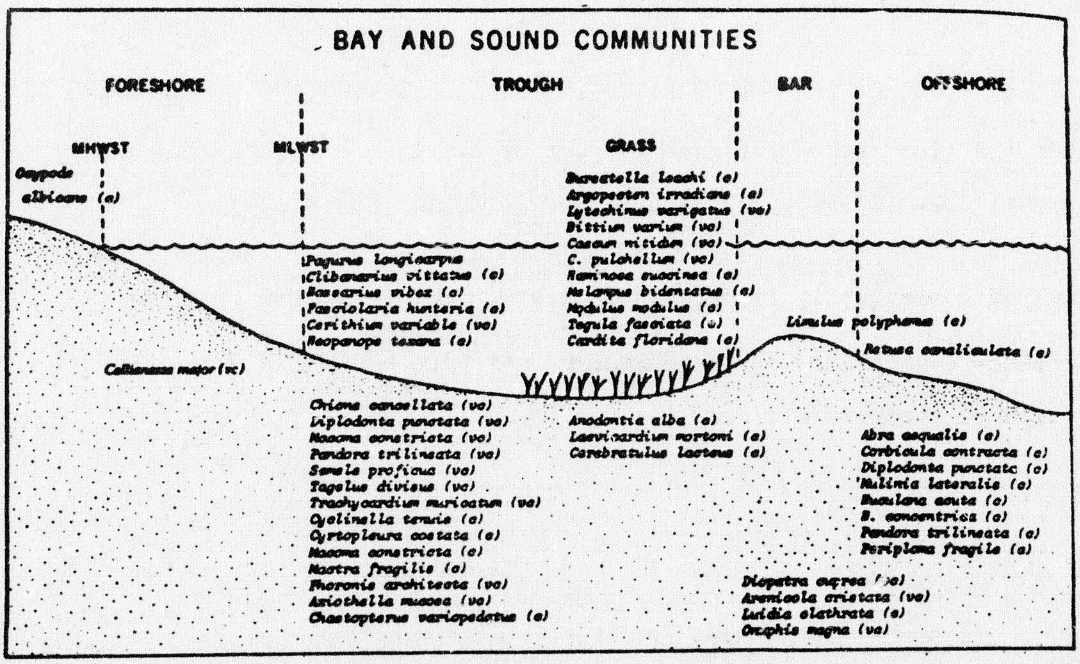

BAY AND SOUND COMMUNITIES
FORESHORE
TROUGH
BAR
OFFSHORE
MHWST
MLWST
GRASS
Ocypode albicans (c)
Bursatella leachi (c)
Argopecten irradians (c)
Lytechinus varigatus (vc)
Bittium varium (vc)
Caecum nitidum (vc)
C. pulchellum (vc)
Haminoea succinea (c)
Melampus bidentatus (c)
Modulus modulus (c)
Tegula fasciata (c)
Cardita floridana (c)
Pagurus longicarpus
Clibanarius vittatus (c)
Nassarius vibex (c)
Fasciolaria hunteria (c)
Cerithium variable (vc)
Neopanope texana (c)
Limulus polyphemus (c)
Retusa canaliculata (c)
Callianassa major (vc)
Chione cancellata (vc)
Diplodonta punctata (vc)
Macoma constricta (vc)
Pandora trilineata (vc)
Semele proficua (vc)
Tagelus divisus (vc)
Trachycardium muricatum (vc)
Cyclinella tenuis (c)
Cyrtopleura costata (c)
Macoma constricta (c)
Mactra fragilis (c)
Phoronis architecta (vc)
Axiothella mucosa (vc)
Chaetopterus variopedatus (c)
Anodontia alba (c)
Laevicardium mortoni (c)
Cerebratulus lacteus (c)
Abra aequalis (c)
Corbicula contracta (c)
Diplodonta punctata (c)
Mulinia lateralis (c)
Nuculana acuta (c)
N. concentrica (c)
Pandora trilineata (c)
Periploma fragile (c)
Diopatra cuprea (vc)
Arenicola cristata (vc)
Luidia clathrata (c)
Onuphis magna (vc)

Figure 71 Bay and sound communities: West Indian affinities. The greatest concentration of animals occurs in the turtle grass community. Scattered south of Cedar Key, common south of Tampa Bay (from Collard and D'Asaro, 1973).

Gulf which show a greater affinity to the fauna characteristic of the West Indies.

West of Louisiana, the Texas coast portrays a different system of bays and estuaries. Here, all but one of the eight major bay systems - most of which are interconnecting, are fronted by an almost continuous chain of barrier islands and peninsulas. Consequently, most of the bays reflect only a minor influence from Gulf waters; furthermore, in the semiarid climate of South Texas, where fresh water drainage is negligible, hypersaline (salinities greater than 40 parts per thousand) conditions persist in the bays and lagoons. In general, a low-to-high salinity gradient exists along the Texas coast from east to south, respectively (U. S. Army Corp of Engineers, 1973).

The most important invertebrates to the Gulf coast include the shrimps, oyster and blue crab. The greater part of the diet of these valuable commercial species consists of detrital or decomposed material.

The three commercially important species of penaeid shrimp (*Penaeus setiferus*, *P. aztecus*, and *P. duorarum*) are dependent upon the estuaries for much of their life cycle.

The oyster, *Crassostrea virginica*, and the brackish water clam, *Rangia cuneata*, are two common and important members of the infauna (living in sediment) of the coastal bays and estuaries along most of the Gulf coast, but their greatest abundance is in the north-central region.

A consumer of decomposing animal matter, the bluecrab, *Callinectes sapidus*, is a resident of the fresh and saltwater marshes of the Gulf coast for the entire year.

The great majority of sport and commercial fishes are dependent upon the marsh-estuary ecosystem at some time during their life cycle. These fishes and some of the more common coastal fauna which are dependent upon the estuaries are listed in Table 38.

Table 38

A partial list of some common
estuarine-dependent species of fishes and shellfishes
(from U. S. Army Corps of Engineers, 1973)

Scientific name	Common name
Trachinotus carolinus	Pompano
Mugil cephalus	Striped mullet
Leiostomus xanthurus	Spot
Cynoscion nebulosus	Spotted seatrout
Sciaenops ocellata	Red-drum

Table 38 (Cont.)

Cynoscion aernarius	White seatrout
Pagonias cromis	Black drum
Brevoortia patronus	Largescale menhaden
Brevoortia smithi	Menhaden
Micropogon undulatus	Atlantic croaker
Scomberomorus maculatus	Spanish mackerel
Archosargus oviceps	Gulf sheepshead
Paralichthys lethostigma	Southern flounder
Penaeus aztecus	Brown shrimp
P. setiferus	White shrimp
P. duorarum	Pink shrimp
Macrobrachium ohione	Giant freshwater shrimp
Xiphopeneus kroyeri	Seabobs
Procambarus blandingi	Crayfish
Callinectes sapidus	Blue crab
Menippe mercenaria	Stone crab
Crassostrea virginica	American oyster
Macrocallista nimbosa	Sun-ray venus clam
Argopecten irradians	Bay scallops
Mercenaria mercenaria	Quahog

Only three species of marine mammals can be expected to utilize the bays or estuaries in the Gulf of Mexico to any extent (Caldwell and Caldwell, 1973). Of these, the bottle-nose dolphin is the only one that occurs throughout the Gulf in inshore waters. The other two mammals are the manatee, and the recently introduced California sea lion.

The principal value of bays to wildlife is the habitat they provide to waterfowl. Gusey and Maturgo (1973) have summarized data pertaining to migration corridors used by diving ducks wintering the Gulf of Mexico.

> The "Eastern Plains Corridor" originates in western Manitoba and eastern Saskatchewan and terminates on the lower Texas coast. Most of the divers using this corridor are redheads, a population comprising almost 3/4 of the redheads in North America which fly this corridor to reach wintering grounds on the Laguna Madre on the lower Texas and upper Mexican coasts. These are joined by lesser scaups and canvasbacks also using this corridor.
>
> The "East Texas Corridor" is a small corridor used by a small number of divers, principally lesser scaups, ring-neck ducks, and canvasbacks, moving from the eastern Dakotas to the Texas coast between Sabine Lake and Matagorda Bay.
>
> The "Missouri River Corridor" extends from central South Dakota to the Gulf coast of Louisiana. Usually lesser scaups, ring-neck ducks, redheads and some canvasbacks, move along this route. Of these, most winter on the Louisiana coast, on the Lacassine National Wildlife Refuge, and in the vicinity of Lakes Pontchartrain and Borgne.
>
> A small flight corridor, the "Prairie Corridor", extends from southwestern Minnesota to the Louisiana coast, a route

followed by some ducks eastward to Florida. Significant concentration points for birds following this route, lesser scaups, ring-neck ducks, canvasbacks, lie east of Grand Chenier and west of Marsh Island, the Mississippi Delta, and Wax Lake southwest of Morgan City.

Two other corridors, the "West Florida Corridor" and "Mobile Bay Corridor" terminate at points along the Gulf coast east of Louisiana, primarily Mobile Bay, Alabama, and the Noxubee National Wildlife Refuge in eastern Mississippi.

(9) Beaches

Much of the northern Gulf coastline is protected from the full force of oceanic waves by barrier islands. The seaward margins of these islands, which are exposed to waves formed at sea, are called high energy beaches. Organisms living in such areas are adapted to survive the scouring force of wave action by burrowing in the sand. The beach flea, *Emerita*, and the bivalve, *Donax*, (among others) can bury themselves almost instantaneously. This ability enables them to live directly in the surf zone (Collard and D'Asaro, 1973). Figure 72 depicts the species commonly found on the high-energy beaches east of the Mississippi; however, many of the same invertebrates are characteristic of the beaches along the barrier islands of Texas (Parker, 1960).

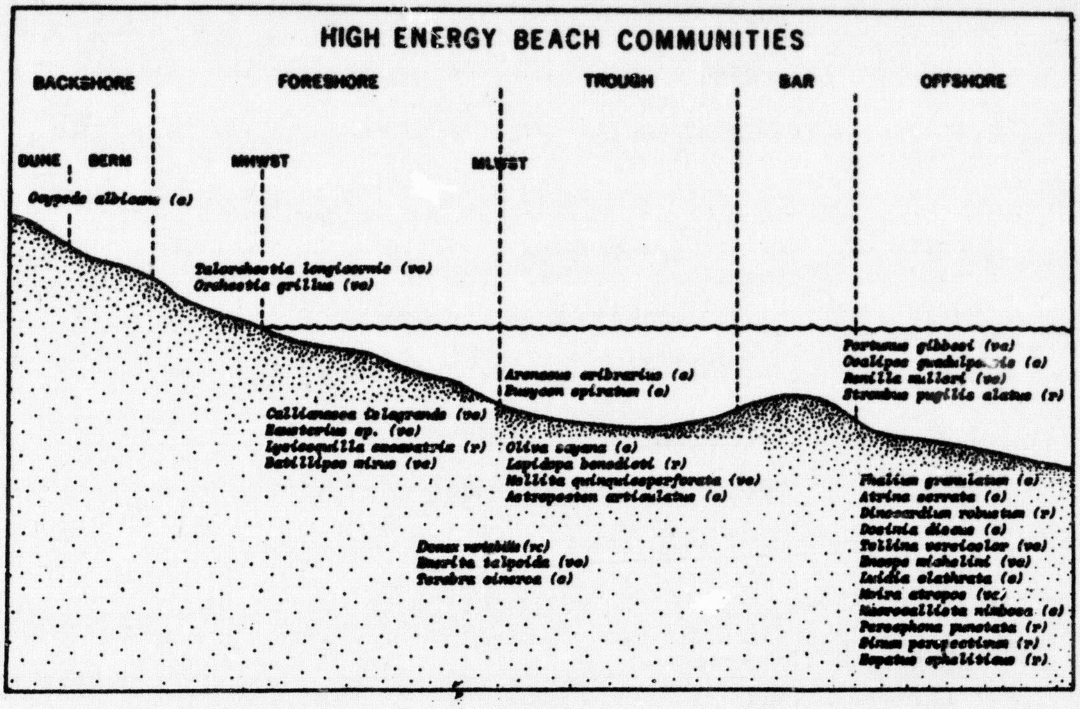

HIGH ENERGY BEACH COMMUNITIES
BACKSHORE
FORESHORE
TROUGH
BAR
OFFSHORE
DUNE
BERM
MHWST
MLWST
Ocypode albicans (c)
Talorchestia longicornis (vc)
Orchestia grillus (vc)
Callianassa islagrande (vc)
Haustorius sp. (vc)
Lysiosquilla ancmatrix (r)
Batillipes mirus (vc)
Arenaeus cribrarius (c)
Busycon spiratum (c)
Oliva sayana (c)
Lepidopa benedicti (r)
Mellita quinquiesperforata (vc)
Astropecten articulatus (c)
Donax variabilis (vc)
Emerita talpoida (vc)
Terebra cinerea (c)
Portunus gibbesi (vc)
Ovalipes guadulpensis (c)
Renilla mulleri (vc)
Strombus pugilis alatus (r)
Phalium granulatum (c)
Atrina serrata (c)
Dinocardium robustum (r)
Dosinia discus (c)
Tellina versicolor (vc)
Encope michelini (vc)
Luidia clathrata (c)
Moira atropos (vc)
Macrocallista nimbosa (c)
Persephona punctata (r)
Sinum perspectivum (r)
Hepatus ephaliticus (r)

Figure High Energy Beach Communities. Composition of these communities is essentially the same from the Mississippi barrier islands to Cape Sable, Florida (from Collard and D'Asaro, 1973).

c. Resources of the Coastal Zone

(1) Land Characteristics

Gulf of Mexico Region

The Gulf of Mexico region extends from the mouth of the Rio Grande at the Texas-Mexico international border to the Florida Gulf Coast and the Bay of Florida side of the Florida Keys to Key West (see Figure 73). Much of the coastal area is marked by barrier island formations similar to the Atlantic shoreline; there is also the vast delta formation of the Mississippi River. The continental shelf is considerably wider in this region than that of the Atlantic coast and the beach slopes are generally flatter. The region has been divided into 8 areas, adapted in part from the National Shoreline Study--Regional Inventory Report--South Atlantic-Gulf Region; Lower Mississippi Region; and Texas Gulf Region prepared by the U.S. Army Corps of Engineers (1971).

The Texas Gulf Coast area is characterized by a nearly continuous chain of barrier islands and beach separated from the heavily indented mainland coastline by an extensive series of inland bays. The principal rivers flowing into the bay indentations along the Texas coast are the Nueces, San Antonio, Lavaca, Colorado, San Jacinto, Trinity, and the Sabine along the Texas-Louisiana line. The ocean shore of these barrier islands is composed mostly of sandy beaches. Of the total state shoreline of about 2,500 miles, approximately 380 miles are sandy beach (see Table 39). The vast bay/estuary zone contains areas of marsh and wetland similar to that found along the Atlantic coast.*

---

* For a generalized portrayal of the coastal landforms of this region and the entire United States, see the National Atlas of the United States "Coastal Landforms" Map, scale 1:7,500,000, pp. 78-79 (1967).

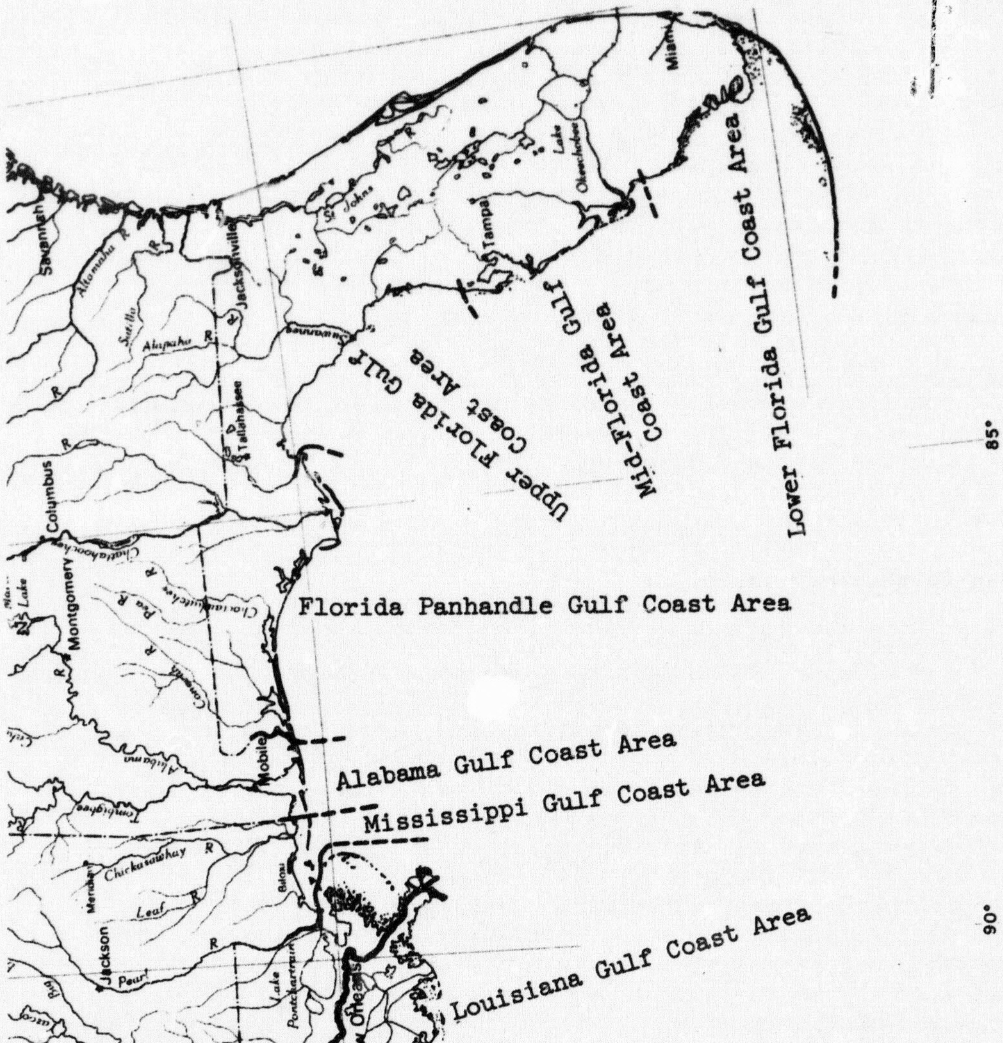

Lower Florida Gulf Coast Area
Mid-Florida Gulf Coast Area
Upper Florida Gulf Coast Area
Florida Panhandle Gulf Coast Area
Alabama Gulf Coast Area
Mississippi Gulf Coast Area
Louisiana Gulf Coast Area
Texas Gulf Coast Area
85°
90°
95°
Miami
Lake Okeechobee
Tampa
St Johns
Jacksonville
Savannah
Altamaha R
Alapaha R
Suwannee
Tallahassee
Columbus
Montgomery
Chattahoochee
Choctawhatchee
Pea R
Mobile
Alabama
Tombigbee
Chickasawhay R
Leaf R
Pearl R
Jackson
Biloxi
Lake Pontchartrain
New Orleans
Baton Rouge
Mississippi
Shreveport
Sabine
Neches
Sam Rayburn Reservoir
Trinity
Houston
Navasota R
Dallas
Fort Worth
Brazos
Whitney Res
Belton Res
Lake Texarkana

Figure 73   Areas in the Gulf of Mexico Region

The Louisiana Gulf Coast area is characterized by vast areas of salt-water marsh lying at or near sea level either partially submerged or subject to tidal overflow, pocked with shallow lakes, bayous, sounds and bays. The entire area is interlaced with a network of channels and canals, and occupies about 3.7 million acres in a broad band across most of the state's interface with the Gulf. This band is from 20 to 30 miles wide in the western portion of the state's coast. The eastern portion of the Louisiana coast is dominated by the Mississippi River Delta which has a frontage over 150 miles along the Gulf, and extends a similar distance inland from the present river mouth.

Because of the coastal configuration, there is a general lack of extensive areas of sandy beach. However, throughout the entire coast area of the state there are many difficult access pockets of beach totalling approximately 835 miles of the overall 1,943-mile state shoreline. Salt-water marsh grass and reeds, belts of wooded swamp and strips of natural levees are the major characteristics of the area.

The Mississippi Gulf Coast area consists mostly of marsh areas and artificially maintained beaches; only on the eastern portion of the state's Gulf shore do narrow marginal natural beaches dot the coastline. The small sandy offshore barrier islands from the actual coastline of the Gulf and are separated from the mainland by the Mississippi Sound. All except Cat Island have beaches on both the Gulf and Sound shorelines, with marsh in the central portion. The Gulf shoreline of these islands totals about 33 miles of which 27 miles are beach. The mainland contains two landlocked bays, Back Bay of Biloxi and St. Louis Bay, as well as the Pascagoula River estuary. The total non-Gulf shoreline of the state's coast is 214 miles in length of which about 70 miles are beach.

Table 39 Beach Shoreline in the Gulf of Mexico Region (in Miles)

Area	Beach	Total Shoreline	Percent Beach
Texas Gulf Coast	380	2,500	15.2
Louisiana Gulf Coast	835	1,943	43.0
Mississippi Gulf Coast	97	247	39.3
Alabama Gulf Coast	249	352	70.7
Florida Panhandle Gulf Coast	770	1,063	72.4
Upper Florida Gulf Coast	5	276	1.8
Mid Florida Gulf Coast	157	1,375	11.4
Lower Florida Gulf Coast	41	1,251	3.3
TOTAL-Gulf of Mexico Region	2,534	9,007	5.9

The Alabama Gulf Coast area varies from sandy coastal beaches to tidal marshes in the two counties bordering the Gulf, and is dominated by the large indentation of Mobile Bay, which is almost entirely enclosed by barrier formations. The total Gulf shoreline of the barrier formations is all beach and is 46 miles in length. Behind these formations are shorelines of mixed marsh and beach; of the 306 miles of bay/sound shoreline of Alabama, 181 miles consist of beach, the remaining being marsh and wetland.

The Florida Panhandle Gulf Coast area extends from the Florida-Alabama line eastward to the Ochlockonee Bay, which is located at the west end of Apalachee Bay. This area is characterized by wide sandy beaches, and barrier islands backed by dunes. Most of the beach material along this reach is white sand composed primarily of quartz. Of the total 1,063 miles of shoreline within this area, 219 miles is ocean/gulf beach that is all sand, and 551 miles is bay/estuary beach. The remaining 293 miles of shoreline consists of marsh.

The Upper Florida Gulf Coast area extends from the Apalachee Bay southward to Anclote Key. This reach is unique in that it is almost devoid of barrier beaches and semi-enclosed bays, consisting almost entirely of low flat salt marshes and mud flats that penetrate inland several miles. Further inland are freshwater marshes and swamps. Nearer the southern portion of the area along the coastline of Hernando and Citrus Counties mangrove growth exists. This section of coast particularly in Apalachee Bay, is essentially free of wave energy that moves littoral materials around along coastlines. Sandy beaches are uncommon and, where present are thin and poorly developed. Less than 5 miles of the total shoreline of 276 miles within this entire area is classified as natural beach.

The Mid-Florida Gulf Coast area consists of barrier islands separated from the mainland by generally shallow tidal lagoons or inlets and from each other by shallow natural passes. The 142 miles of shoreline fronting the Gulf along this area, which includes the urban concentrations surrounding Tampa, St. Petersburg, Sarasota and Fort Meyers, consists of natural beaches that are composed of fine white sand that contains a considerable amount of shell. The land along the shorelines of nearly all the mainland coastline and the mainland side of the barrier islands within this area, approximately 1,230 miles total, is low and marshy.

The Lower Florida Gulf Coast area is characterized mostly by numerous low flat islands covered with mangrove growth, particularly in the area of the Ten Thousands Islands and the mainland shoreline of the

Everglades. The Everglades consists of low salt marshes, tidal creeks and shallow bays surrounded by mangrove. The coast is broken by several tidal rivers and numerous creeks, which flow through the mangrove and salt marshes from a system of shallow bays parallel to the coast 6 to 10 miles inland. The length of tidal shoreline of this area is indeterminate due to the numerous islands, bays, rivers and tidal creeks; however, it is estimated to be over 1,250 miles. The overall low, flat mangrove character of the area is exemplified in that less than 40 miles is classified as beach; these beaches, however, are narrow and relatively steep.

(2) Land Ownership

Gulf of Mexico Region

Shoreline ownership in the Gulf Coast area is predominantly private, as indicated in the table below. Ownership by the Federal Government is extremely limited in the Mid-Florida, Mississipi and Alabama areas, however, greater concentrations are located in the Lower Florida (recreation/conservation-oriented), Florida Panhandle (military-oriented, particularly at Pensacola), Louisiana Gulf Coast (conservation-wildlife-oriented), and Texas Gulf Coast (recreation/wildlife-conservation-oriented) areas. Non-Federal public (state/local) ownership is greatest in the Louisiana shoreline reaches where the state owns several wildlife-conservation management areas.

Table 40 Land Ownership of the Gulf of Mexico Region Shoreline

	Total Length of Shoreline	Federal		State/Local		Private	
Area	Miles	Miles	%	Miles	%	Miles	%
Texas Gulf Coast	2,500	390	15.6	50	2.0	2,060	82.4
Louisiana Gulf Coast	1,943	245	12.6	332	17.1	1,366	70.3
Mississippi Gulf Coast	247	33	13.4	43	17.4	171	69.2
Alabama Gulf Coast	352	2	0.6	13	3.7	337	95.7
Florida Panhandle Gulf Coast	1,063	221	20.8	107	10.1	735	69.1
Upper Florida Gulf Coast	276	44	15.9	26	9.5	206	74.6
Mid-Florida Gulf Coast	1,375	27	2.0	36	2.6	1,312	95.4
Lower Florida Gulf Coast	1,251*	238	19.0	21	1.7	895	71.5
TOTAL-Gulf of Mexico Region	9,007	1,200	13.3	628	7.0	7,082	78.6

* Mileage does not total because ownership is uncertain for some islands in the Florida Keys.

(3) Land Use

The land use of the Texas Gulf Coast is variable in type and intensity on both the mainland and the barrier formations. Over 70 percent of the total shoreline is undeveloped as shown in the table below. However, the areas of developed shoreline vary from recreation-oriented, resort/vacation cottage or marina facilities to the intensely developed urban industrial-commercial land uses.

Table 41 Shoreline Use in the Gulf of Mexico Region (in Miles)

Area	Public Recreation	Private Recreation	Non-Recreation Development	Undeveloped	Total
Texas Gulf Coast	406	162	112	1,820	2,500
Louisiana Gulf Coast	21	32	50	1,840	1,943
Mississippi Gulf Coast	31	106	9	101	247
Alabama Gulf Coast	32	210	5	105	352
Florida Panhandle Gulf Coast	99	521	166	277	1,063
Upper Florida Gulf Coast	3	12	33	228	276
Mid-Florida Gulf Coast	45	81	320	929	1,375
Lower Florida Gulf Coast	20	22	245	964	1,251
TOTAL-Gulf of Mexico Region	657	1,146	940	6,264	9,007

The land use on the barrier formations is generally a function of proximity to population centers and availability of access. The beaches facing the Gulf are generally suitable for recreation-oriented activities. Padre Island, which stretches from the Texas-Mexico border north to near Corpus Christi Bay, is now a National Seashore and retains its natural conditions, except for recreation facilities at its north end. However, some areas to the north and south are being rapidly developed for residential and commercial uses or are under similar development pressures. Mustang Island is also a highly developed recreation center for the Corpus Christi metropolitan area, with beach homes, resorts, water-oriented recreation facilities and commercial establishments. Galveston Island and Bolivar Peninsula contain the Galveston urban area, and are both highly developed. The Galveston Bay area contains the largest concentration of shoreline development on the entire Texas coast, consisting of commercial and residential uses, and large industrial complexes which relate to fishing, shipping, and offshore oil and gas exploration and production. The largest port facilities of the entire Gulf Coast region are located here, with the other significantly developed area being Corpus Christi.

The Louisiana Gulf Coast is largely undeveloped along the shoreline, with more intensive land uses concentrated in those inland areas more suitable for development. The vast, broad areas of coastal marsh preclude beach-oriented activities in most areas due to the general lack of sandy beaches and the lack of access to shoreline areas. Existing land use consists of small communities oriented to the seafood industry, and to support offshore oil and gas operations. Severe developmental constraints, including susceptibility of hurricane surges, have kept permanent shoreline developments to a minimum.

Industry in the coastal zone is dominated by petroleum refining, petrochemical production, ship building, food processing, (including seafood), and primary metals, with petroleum refining and petrochemicals being the most significant. Activities relating to the extraction, transportation and processing of oil and gas (including the offshore component) are significant land uses in the coastal zone. The majority of oil and gas wells are in swamp and marsh areas, and most of the state's total production comes from the coastal zone parishes. Agriculture is also a significant activity in the coastal zone primarily rice and sugar cane production.

The Mississippi Gulf Coast land use is marked by a diversity of a generally highly developed mainland shoreline on the Mississippi Sound, and a generally undeveloped shoreline on the barrier formations facing the Gulf. Part of these barrier formation islands are now within the Gulf Islands National Seashore. Very little differentiation remains between communities along the coastline, where a high density urban corridor has recently taken form due partly to great expansion of the tourist-recreation industry. The only major breaks in this linear development are the result of natural features such as bays, estuaries, rivers and tidal marshes.

On the Alabama Gulf Coast, topography has imposed historical constraints on development patterns and land use allocations. Mobile Bay and its delta to the north, as well as other low elevation areas subject to flooding, are generally timbered and undeveloped, while development has been directed to higher elevations, both along the coast and inland.

The coastal areas, especially the barrier formations are coming under increased pressure for commercial and recreational development. Many smaller communities exist which consist of residential areas, cottages, hotels and motels which accomodate tourist and seasonal visitors. However, part of these barrier formations are included in the Gulf Islands National Seashore, and will retain their natural conditions.

The Florida Panhandle Gulf Coast area land use is in part a function of the physical differences of the barrier formations and the mainland bay areas. Shoreline uses are highly variable. The barrier islands are generally suitable for beach recreation-oriented activity and considerable lengths are used for recreation purposes. In recent years, land use dedicated to the tourist and recreation industry has greatly increased. The area's development, however, is also focused on its mainland shoreline with naval activities and shipping and marine resources predominating. Industrial development has also gravitated to the area because of available transportation and production facilities.

The Pensacola Bay area contains a long uninterrupted stretch of urbanized, industrialized shoreline. The most intense tourism and recreation-related land use is on the Gulf to the west of Panama City, where an almost unbroken commercial strip development consisting of motels, condominiums, restaurants, summer homes, etc., has developed. East of Panama City, however, the quality of the beach deteriorates, coastal land use becomes much less intense, populations are lower, and only a few summer homes exist.

Upper Florida Gulf Coast land use is extremely extensive in character. Population densities are among the lowest in the state, and most of the area is commercial forest land or wetland. Very little use is made of the shoreline, due largely to its inaccessibility. Several conservation-wildlife management areas are located in this area, to be discussed later in this section. Residential and commercial development is limited to the few towns and communities located throughout the area. Industry is related to forestry and lumbering, agriculture, and fishing.

The Mid-Florida Gulf Coast area again finds urban development and beach-oriented commercial and recreation activities mixed with pockets of undeveloped shoreline. The major urban area in this stretch is the Tampa-St. Petersburg-Clearwater metropolitan complex, with a population of over 1.5 million, and the Sarasota-Bradenton area. Industrial expansion has occurred due to the transportation advantages of this coastal zone, which has reinforced the historic shoreline-oriented development pattern. Presently, 82 percent of this region's developed land is in its coastal zone. Other stretches of the gulf and bay shoreline throughout this area are developed for residential, resort and tourist accomodation purposes. There are many apartments, motels, and concession facilities catering to tourists and beach visitors. Several of the undeveloped natural areas have been reserved as Federal and State conservation-wildlife management areas.

The Lower Florida Gulf Coast area is largely undeveloped. Population densities are very low, land transportation access is generally lacking, and land use is extensive in character. Nodes of recreation-residential development occur at Naples, on Marco Island and at the town of Everglades. Much of this coastal zone is composed of mangrove growth and marsh area, and is part of the Everglades National Park. The 20 miles of shoreline north of the Naples area consist of beach that is used for private and public recreation.

(4) Military Uses

There is considerable military ownership and use of the coastal zone along the Gulf of Mexico. Facilities located on the coast of this region are listed in Table 42 (some of the facilities listed are not currently active and may be idle or used for other purposes such as recreation or wildlife conservation). Military operations in these coastal areas of the Gulf of Mexico region may include test flights, refueling, all weather fleet training, all weather training drones, carrier and submarine operations, rockets, bomb anti-submarine practice and anti-aircraft and surface gunnery. Military operations which may affect normal use of the coastal areas are indicated in such guides as the Notice to Mariners Publications, U.S. National Ocean Survey maps, and U.S. Naval Oceanographic Office maps and publications.

(5) Recreation Resources

The Gulf coast offers a wide variety of recreational opportunities. Following are descriptions of the various kinds of outdoor recreation areas, and historical and archaeological sites. Wildlife refuges and management areas are discussed in the next section. Figure 74 indicates the distribution of the major Federal and State recreation areas, while Table 43 lists the facilities available within the Gulf Coast region, their location and acreage (where available). In addition to these areas, there are various county and municipal recreation areas used by local residents and tourists alike.

Table 42 Military Facilities of the Gulf of Mexico Region

- Area
    - Facility

- Texas Gulf Coast Area
    - Corpus Christi Naval Air Station
    - Waldron Naval Auxiliary Landing Field
    - Cabaniss Naval Auxiliary Landing Field
    - Fort Travis Army Reservation
    - Matagorda Island Bombing and Gunnery Range
    - Galveston Coast Guard Station
    - Ellington Air Force Base

- Louisiana Gulf Coast Area
    - New Orleans Naval Air Station
    - New Orleans Naval Ammunition Depot

- Mississippi Gulf Coast Area
    - Keesler Air Force Base

- Alabama Gulf Coast Area
    - Dauphin Island Air Force Defense Control Station
    - Mobile Harbor Coast Guard Station

- Florida Panhandle Gulf Coast Area
    - Pensacola Naval Air Station
    - Saufley Naval Air Station
    - Whiting Naval Air Station
    - Ellyson Naval Air Station
    - Chevalier Naval Air Station
    - Pensacola Navy Gunnery Range
    - Eglin Air Force Base
    - Live Oaks Naval Reservation
    - Tyndall Air Force Base
    - Naval Mine Defense Laboratory

- Upper Florida Gulf Coast Area

- Mid-Florida Gulf Coast Area
    - MacDill Air Force Base
    - Egmont Key Coast Guard Station
    - Coast Guard Loran Transmitting Station

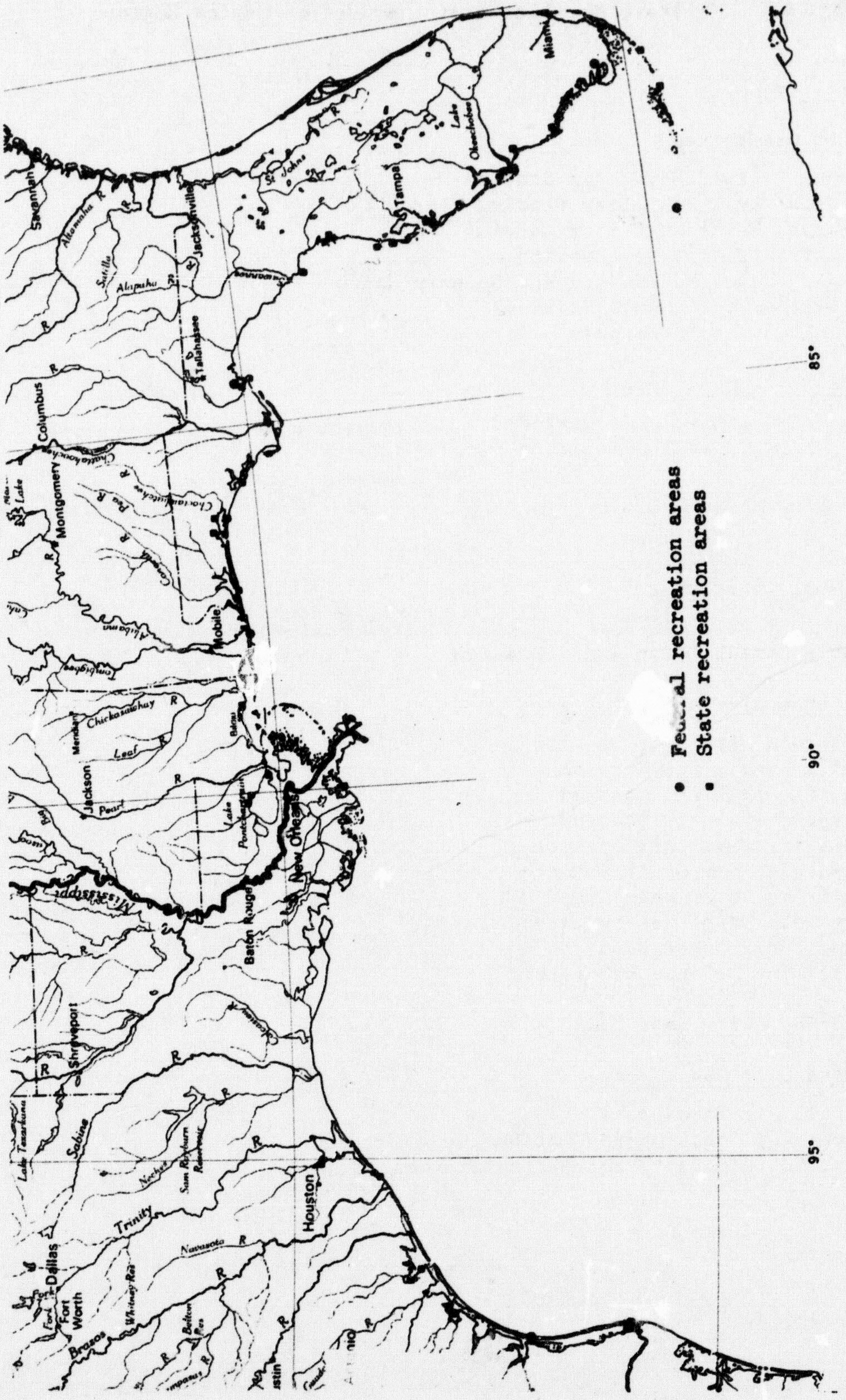

● Federal recreation areas
■ State recreation areas
85°
90°
95°
Savannah
Altamaha R
Satilla
Alapaha R
Jacksonville
St Johns
Tampa
Lake Okeechobee
Miami
Tallahassee
Suwannee
Columbus
Montgomery
Chattahoochee
Choctawhatchee
Pea R
Mobile
Alabama
Tombigbee
Chickasawhay R
Meridian
Leaf R
Jackson
Pearl R
Lake Pontchartrain
New Orleans
Baton Rouge
Mississippi
Shreveport
Sabine
Lake Texarkana
Neches
Sam Rayburn Reservoir
Trinity
Houston
Navasota R
Dallas
Fort Worth
Brazos
Whitney Res
Belton Res
Lampasas R
Austin
Antonio R

Figure 74 Federal and State Recreation Areas in the Gulf of Mexico Region

Table 43 **Existing State and Federal Recreation Areas**

Area Name	Location	Acreage
Texas Gulf Coast Area		
Padre Island National Seashore		
Brazos Island State Park	Cameron Co.	217
Copano Bay Causeway State Park	Aransas Co.	6
Goose Island State Park	"	307
Port Lavaca Causeway State Park	Calhoun Co.	2
Indianola State Park	"	300
Velasco State Park	Brazoria Co.	1,921
Sea Rim State Park	Jefferson Co.	
Louisiana Gulf Coast Area		
Fort Pike State Park	Orleans Parish	125
Fontainebleau State Park	St. Tammy Parish	2,605
Grand Isle State Park	Plaquemines Parish	125
Rutherford Beach State Park	Cameron Parish	
Mississippi Gulf Coast Area		
Gulf Islands National Seashore		
Magnolia State Park	Harrison Co.	
Alabama Gulf Coast Area		
Gulf Islands National Seashore		
Gulf State Park	Baldwin Co.	4,807
Fort Morgan State Park	"	410
Meyer State Park	"	
Alabama Point State Park	"	
Florida Panhandle Gulf Coast Area		
St. Joseph State Park	Gulf Co.	2,516
St. Andrews State Park	Bay Co.	1,022
Grayton Beach State Park	Walton Co.	350
Basin Bayou State Park	"	287
Fred Gannon Rocky Bayou State Park	Okaloosa Co.	632
John C. Beasley State Park	"	23
Fort Pickens State Park	Escambia Co.	1,659
St. George Island State Park	Franklin Co.	
Gulf Islands National Seashore		
Upper Florida Gulf Coast Area		
Anclote Key State Park	Pasco Co.	

Table 43 Existing State and Federal Recreation Areas (cont')

Area Name	Location	Acreage
Mid-Florida Gulf Coast Area		
Caladesi Island State Park	Pinellas Co.	
Oscar Scherer State Park	Sarasota Co.	463
Koreshan State Park	Lee Co.	305
Lower Florida Gulf Coast Area		
Everglades National Park		1,400,533
Long Key State Park	Monroe Co.	292
Bahia Honda State Park	"	270
Fort Jefferson National Monument	"	47,125
Collier-Seminole State Park	Collier Co.	6,423

The National Park Service of the U.S. Department of the Interior administers two national seashores and a national park along the Gulf coast. These are Gulf Islands National Seashore, Padre Island National Seashore and Everglades National Park. These areas have been set aside as units of the National Park System because of the national interest in their natural, historical and recreational opportunities such as camping, swimming, boating, fishing, picnicking, nature study and sightseeing.

State parks within the Gulf region are relatively spacious areas established primarily to preserve natural features of exceptional quality, historic, archeological, scientific, or other distinctive characteristics, and have been developed for high density use.

The Gulf coast contains large numbers of archeological sites which provide evidence essential to the understanding of aboriginal cultures of the area. The known sites along the coast represent the various stages in cultural development of the prehistoric Indian inhabitants. A study of archeological resources in the Texas coastal zone (Briggs, 1971) states that there are 1,339 sites on record in their study area which included 35 counties in the Texas coastal lowlands. In Florida, the Coastal Coordinating Council has mapped approximately 350 known sites in the Gulf coastal counties. Numerous sites exist in the coastal parishes of Louisiana, and in the coastal counties of Mississippi and Alabama.

Offshore archaeological and historic features include sunken ships dating from the 1500's to recent, and possible former habitation sites of early Gulf Coast natives. Rapid sedimentation in the offshore Mississippi delta region has most likely obscured all but the most recent sites, however areas in both the eastern and western Gulf which have undergone little recent sediment accumulation, offer more discovery promise.

The numerous historic sites located in the Gulf Coast region date from the earliest Spanish explorations of the area in the early 1500's. A number of these sites are included in the National Register of Historic Places or are National Historic Landmarks. These sites include forts, churches, buildings of architectural interest, homes of important historic figures, sites of important battles and Indian villages.

Saltwater sport fishing is one of the most popular outdoor recreation activities in the Gulf Coast region and is a significant factor in the economy of the coastal zone. Estimates of the sport fishing effort in the Gulf have been made by the National Marine Fisheries Service in the 1970 Saltwater Angling Survey (U.S. Dept. of Commerce, 1973d). Saltwater sport fishing was defined for the purpose of the survey as "all fishing in the oceans, bays, estuaries and tidal portions of rivers." According to the survey there were 2.3 million saltwater anglers in the Gulf during 1970. These anglers caught 486 million pounds of fish and spent $405 million. The fishing effort and pounds of catch in the Eastern Gulf (east of the Mississippi River mouth) was approximately double that in the Western Gulf. The sports catch was approximately 29 percent of the total poundage of Gulf fishery landings. These data fall within the estimation made by Taylor (Taylor, J.L., et al., 1973) who predicted that sport fish landings in the Gulf would approximate one-third to one-half the volume of commercial landings (2 million pounds). The sportsmen expenditure was 2.4 times the commercial dockside value (National Marine Fisheries Service, 1973).

(6) Conservation Areas

A considerable portion of the coastal zone in the Gulf of Mexico region is wetland/marsh in character. Over 90 percent of the total length of shoreline is non-beach, much of which is undeveloped wetland. These wetlands areas are vital not only for reproduction and breeding grounds, flood plain protection, erosion control and widlife habitat, but also for aesthetic and recreation purposes.

The Gulf Coast States are in the process of establishing coastal zone management mechanisms pursuant to the Federal Coastal Zone Management Act of 1972 for the purpose of planning and regulating the uses that can be made of this important area. State laws, such as the Texas Coastal Public Lands Management Act of 1973, the Alabama Coastal Area Act of 1973, the Mississippi Coastal Wetlands Protection of 1973 and the Florida Environmental Land and Water Management Act of 1972 have been enacted to provide guidance and coordination of coastal development and use activities.

Numerous Federal and State conservation-wildlife management areas and preserves have already been established that serve to protect large sections of the Gulf coastal zone from intense development pressures. Figure 75 shows the distribution of Federal and State conservation-wildlife areas currently existing, and Table 44, following the map, lists the names of these areas and their acreage (where available).

Unique to Florida are the aquatic preserves that the State owns by virtue of its sovereignty over some 10,000 square miles of submerged tidal lands offshore from its extensive Atlantic and Gulf coastlines and in its numerous bays, estuaries and lagoons. A State-wide system of aquatic preserves was established to set aside certain exceptionally valuable and representative areas for perpetual public enjoyment, and to preserve important natural ecological systems. The State of Florida Board of Trustees of the Internal Improvement Trust Fund has management responsibility at the present time.

(7) Transportation

Major Ports and Shipping

The economic structure of the Gulf of Mexico coast is highly dependent on its transportation systems in general,

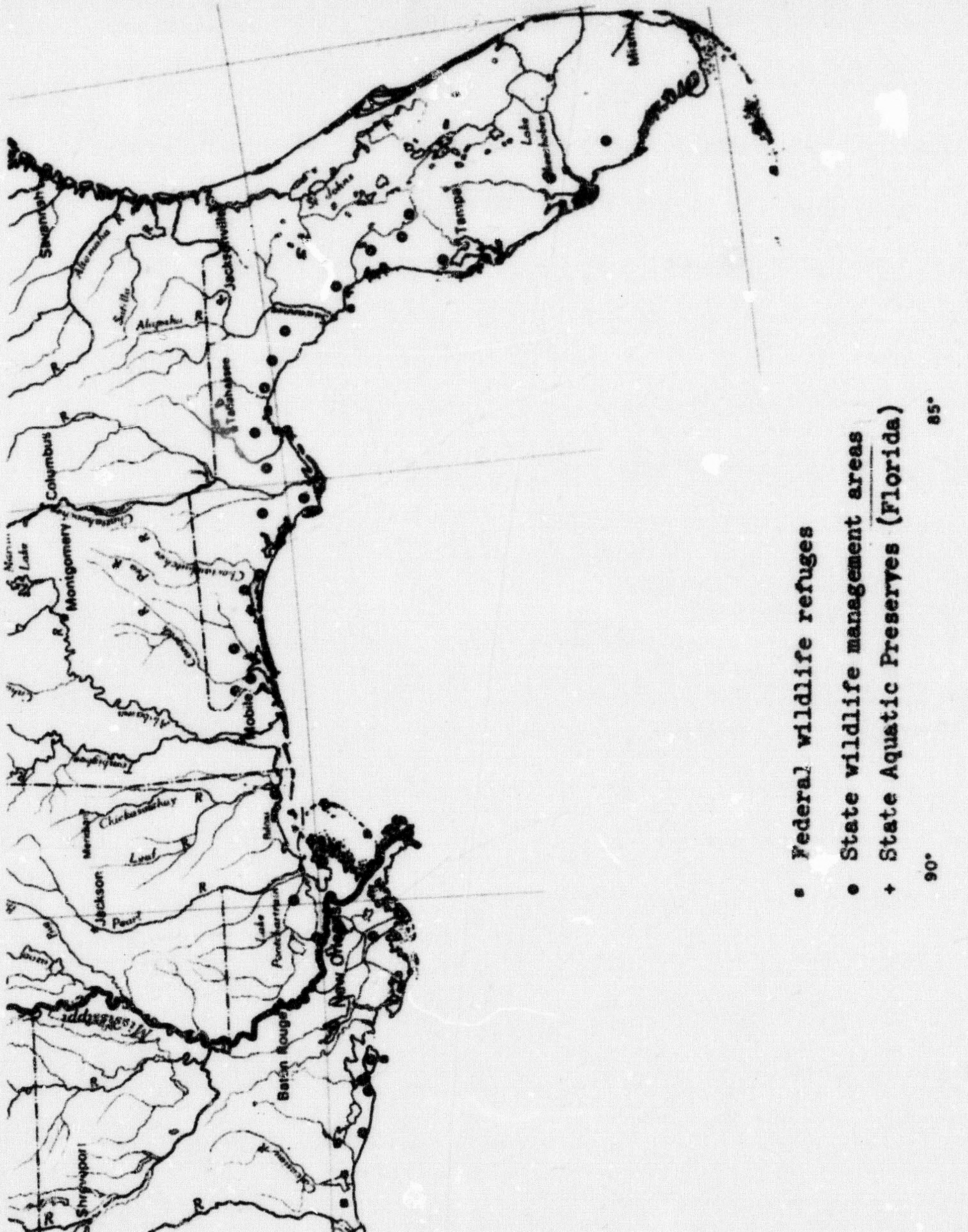

▪ Federal wildlife refuges
● State wildlife management areas
+ State Aquatic Preserves (Florida)
85°
90°
95°
Houston
Dallas
Fort Worth
Brazos
Trinity
Sabine
Shreveport
Baton Rouge
New Orleans
Lake Pontchartrain
Mississippi
Pearl
Jackson
Mobile
Montgomery
Columbus
Tallahassee
Jacksonville
Tampa
Lake Okeechobee
Miami

Figure 75 Federal and State Wildlife Management Areas in the Gulf of Mexico Region

Table 44 Existing Federal and State Conservation-Wildlife Management Areas

Area	Acreage
Name	
Texas Gulf Coast Area	
Laguna Atascosa National Wildlife Refuge	45,204
San Bernard National Wildlife Refuge	15,414
Aransas National Wildlife Refuge	90,069
Brazoria National Wildlife Refuge	9,625
J. D. Murphree State Wildlife Management Area	
Louisiana Gulf Coast Area	
Sabine National Wildlife Refuge	142,846
Lacassine National Wildlife Refuge	31,776
Rockefeller State Wildlife Refuge	
Paul J. Rainey Wildlife Refuge and Game Preserve	
Vermilion Bay State Wildlife Refuge	
Russell Sage State Wildlife Refuge	
Wisner State Wildlife Management Area	
Pointe au Chein State Wildlife Management Area	
Salvador State Wildlife Management Area	
Bonnet Carre State Wildlife Management Area	
Bohemia State Wildlife Management Area	
Pass a Loutre State Wildlife Management Area	
Biloxi State Wildlife Management Area	
Goose Point State Game Preserve	
Breton National Wildlife Refuge	9,047
Delta National Wildlife Refuge	48,799
Shell Keys National Wildlife Refuge	8
Mississippi Gulf Coast Area	
Red Creek State Wildlife Management Area	
Alabama Gulf Coast Area	
Florida Panhandle Gulf Coast Area	
St. Vincent National Wildlife refuge	12,490
St. Regis State Wildlife Management Area	
La Floresta State Wildlife Management Area	
Blackwater State Wildlife Management Area	
Eglin State Wildlife Management Area	
Point Washington State Wildlife Management Area	
Roy D. Gaskin State Wildlife Management Area	

Table 44 Existing Federal and State Conservation-Wildlife Management Areas (cont.)

Area Name	Acreage
Florida Panhandle Gulf Coast Area (cont.)	
Ed Ball State Wildlife Management Area	
Liberty State Wildlife Management Area	
Fort Pickens State Aquatic Preserve	
Yellow River Marsh State Aquatic Preserve	
Rocky Bayou State Aquatic Preserve	
St. Andrews State Aquatic Preserve	
St. Joseph Bay State Aquatic Preserve	
Apalachicola Bay State Aquatic Preserve	
Alligator Harbor State Aquatic Preserve	
Upper Florida Gulf Coast Area	
St. Marks National Wildlife Refuge	64,074
Aucilla State Wildlife Management Area	
Tide Swamp State Wildlife Management Area	
Cedar Keys National Wildlife Refuge	379
Gulf Hammock State Wildlife Management Area	
Chassahowitzka National Wildlife Refuge	30,072
Leon-Wakulla State Wildlife Management Area	
Steinhatchee State Wildlife Management Area	
Citrus State Wildlife Management Area	
Croom State Wildlife Management Area	
Waccasassa Bay State Aquatic Preserve	
St. Martins Marsh State Aquatic Preserve	
Cedar Keys National Wilderness Area	
Mid-Florida Gulf Coast Area	
Pinellas National Wildlife Refuge	377
Passage Key National Wildlife Refuge	36
Passage Key National Wilderness Area	
Island Bay National Wildlife Refuge	20
Pine Island National Wildlife Refuge	31
Caloosahatchee National Wildlife Refuge	40
Matlacha Pass National Wildlife Refuge	10
J. N. "Ding" Darling National Wildlife Refuge	4,788
Bull Creek State Wildlife Management Area	
Richloam State Wildlife Management Area	
Cecil Webb State Game Preserve	
Caladesi Island State Aquatic Preserve	
Boca Ciega Sound State Aquatic Preserve	
Cockroach Bay State Aquatic Preserve	
Boca Ciega Bay State Aquatic Preserve	
Pine Island Sound State Aquatic Preserve	

Table 44 Existing Federal and State Conservation-Wildlife Management Areas (cont.)

Area Name	Acreage
Lower Florida Gulf Coast Area	
Corkscrew Swamp Sanctuary	
National Key Deer Refuge	4,642
Great White Heron National Wildlife Refuge	2,764
Key West National Wildlife Refuge	2,019

and on water transportation in particular. The region has developed an intricate navigation infrastructure which handles both deep-draft ocean shipping and inland waterway traffic. The table below indicates the commercial cargo handled in 1971 by the Gulf Coast ports. The ports of New Orleans and Houston are the second and third largest in the United States, respectively, in terms of tonnage handled. Texas rivals New York as the leading seafaring state, and Louisiana is third. Crude petroleum and petroleum products are the largest commodity handled Gulf-wide, with agricultural produce second.

Numerous navigable waterways provide links between the coastal ports and the interior ports. Much of the inland waterway traffic is by barge. The major coastal inland waterway is the Gulf Intracoastal Waterway, which extends from Brownsville, Texas, to near Apalachee Bay, Florida. The Waterway is 1,113 miles in length; the most heavily travelled portion is between the Mississippi River (at New Orleans), and the Sabine River on the Louisiana-Texas border.

Table 45 Shipping Commerce, 1971 - Gulf of Mexico Areas, with Major Ports

Area	Total Commerce (tons)	Principal Ports
Florida Gulf Coast	40,063,000	Tampa, Pensacola, Panama City
Alabama Gulf Coast	24,919,224	Mobile
Mississippi Gulf Coast	11,414,000	Pascagoula, Gulfport
Louisiana Gulf Coast	139,289,000	New Orleans, Lake Charles
Baton Rouge	47,017,000	
Texas Gulf Coast	188,471,000	Houston, Beaumont, Port Arthur Corpus Christi, Texas City

Source: U.S. Army Corps of Engineers, 1972.

Pipelines

Because of the vast petroleum resources contained and/or processed within the west and central Gulf Coast region, portions of the Texas and Louisiana coast have developed some of the greatest concentrations of pipelines in the world. This infrastructure includes gas as well as crude oil and produce pipelines, and ties in offshore and onshore production. These lines transmit enormous quantities of gas and oil to processing and consuming centers throughout the Nation. As production and processing activities are less in the eastern Gulf area, the density of lines drops sharply. There are virtually no crude oil product lines in Florida, and only one major natural gas line in its coastal area.

Major Interstate Highways

Highways criss-cross the coastal zone to serve the people and commodity movement requirements of the Gulf Coast region, with trucking providing a large segment of the goods movement capability. The main movement corridors are near the population and industrial centers of Houston-Galveston, New Orleans-Baton Rouge, Mobile and Tampa-St. Petersburg. Because of the coastline irregularities and vast areas of wetland, highways are somewhat inland, with major arteries extending to population-industrial centers on the coast proper.

Railroad System

The Gulf Coast region is served by a network of railroads, principally freight-oriented, that interconnect the entire region and tie it to inland areas and the rest of the Nation. Railroad trackage is greatest in the Western Gulf because the commodity movement demands of this portion of the region are greatest. Railroads support all major ports with sufficient trackage that generally exceeds existing volume capacity requirements. Because of the physical constraints to construction of railroads along the immediate coast, the main lines or corridors throughout the Gulf Coast region, similar to the highways, are generally inland somewhat. Spur lines serve the population-industrial centers and port facilities along the coast proper.

Aviation Routes

Air service, both passenger and cargo, exists to all major cities in the Gulf of Mexico region. The largest airports are Houston Intercontinental and William P. Hobby at Houston, New Orleans International, Mobile, and Tampa International and St. Petersburg-Clearwater International in Florida.

(8) Historical and Projected Economic Growth in the Gulf of Mexico Region

The data used in this section is based on the latest OBERS data from the Bureau of Economic Analysis (BEA), U.S.

Department of Commerce, Washington, D.C. During September, 1972, the U.S. Water Resources Council published the 1972 OBERS Projections of economic activity in the United States prepared by the U.S. Department of Commerce and the U.S. Department of Agriculture. These projections consist of historical and projected data incorporating population, employment, and income and earnings information classified by state and BEA region. The 1972 projections utilized population projections published by the U.S. Bureau of the Census, and were based on the Series C fertility rates. Since that time the projections of economic activity in the various OBERS Bureau of Economic Analysis Economic Areas based on the Series E fertility rates have become available. Projections based on Series E forecast a lower level of population in future years.

The BEA Economic Areas divide the Gulf of Mexico region into three sections. The coastal region of Texas comprises the Western Gulf of Mexico region; the coastal portion of Louisiana and part of Mississippi comprises the Central Gulf of Mexico region; and the remaining portion of the Mississippi coastal area, the Alabama coastal area and the western coastal area of Florida comprises the Eastern Gulf of Mexico region. A comparison of the population, employment and personal income of the inhabitants of this region with the total United States population, employment and personal income is shown in the table below. Perhaps the most significant relationship revealed is that in all three regions of the Gulf, their percentage of population of the total U.S. population is higher than their percentage of the national employment and personal income.

Table 46 Population, Employment and Income by Regions and U.S., 1970

		Gulf of Mexico		
	Total U.S.	Western	Central	Eastern
Total Population	203,857,864	4,883,064	2,900,230	3,267,717
% of U.S.	---	2.4	1.4	1.6
Total Employment	79,306,527	1,816,283	963,028	1,138,419
% of U.S.	---	2.3	1.2	1.4
Total Personal Income*	$708,583,931	$15,059,700	$7,973,192	$9,150,233
% of U.S.	---	2.1	1.1	1.3

* Total personal income in thousands of 1967 dollars.

Source: 1972-E OBERS Bureau of Economic Analysis Economic Areas, U.S. Department of Commerce.

A significant economic trend that has been present during the last decade in the Gulf of Mexico region has been the decline in farm employment and the increase in employment in manufacturing and such non-manufacturing categories as mining, construction, transportation and services. Total cash farm income has increased during the last decade, however, and the indexes of production provided in the OBERS report project increases in the production of crops and livestock in the future. Employment in the various manufacturing industries has increased during the past decade, and the value added by manufacture has increased within the entire Gulf region. The OBERS indexes of production for selected industries indicate that increases in output for all the various manufacturing activities are projected for the future. Within the non-manufacturing categories, increases in output are projected for crude petroleum and natural gas in each of the five States bordering the Gulf of Mexico.

The following table presents the earnings data for selected industries in the Gulf of Mexico regions during 1970 .

Table 47 Total Earnings of Selected Industries, 1970
(in thousands of 1967 dollars)

Industry	Total U.S.	Gulf of Mexico Western	Gulf of Mexico Central	Gulf of Mexico Eastern
Agriculture, Forestry and Fisheries	19,640,721	408,029	226,622	287,381
Mining	5,647,503	448,490	407,977	39,610
Manufacturing	156,291,199	2,415,108	1,137,201	1,216,005
Services	85,077,671	1,792,200	884,246	1,024,935
Government	99,310,475	2,350,310	1,073,445	1,518,090

Source: 1972-E OBERS Projections (Volume 5), U.S. Department of Commerce

The following economic summaries for the five States bordering the Gulf of Mexico present information concerning the economic climate on a statewide basis, and therefore are more general than economic data pertaining strictly to the Gulf coastal portions of each of the states. However, economic factors occurring outside the Gulf coastal zone may have effects over larger geographic areas that include the coastal zone. In addition to the OBERS study, data were drawn from publications prepared by the Research Department of the Federal Reserve Bank of Atlanta, and from statistical tables contained in the Texas Almanac and State Industrial Guide, published by the A. H. Belo Corporation in 1973.

Table 48 Total Personal Income and Per Capita Income in the Gulf Coastal States

	Total Personal Income (Million Dollars)			Per Capita Income		
State	1962	1972	Percent Change	1962	1972	Percent Change
Texas	20,518	47,121	+129.7	2,019	4,045	+100.3
Louisiana	5,901	13,179	+123.3	1,764	3,543	+100.9
Mississippi	2,978	7,099	+138.4	1,328	3,137	+136.2
Alabama	5,317	12,004	+125.8	1,600	3,420	+113.8
Florida	11,039	31,779	+187.9	2,022	4,378	+116.5

Table 49 Total Manufacturing Employment in the Gulf Coastal States

State	1962	1972	% Change
Texas	500,000	741,000	+48.2
Louisiana	139,000	179,000	+28.8
Mississippi	128,000	205,000	+60.2
Alabama	240,000	328,000	+36.7
Florida	222,000	335,000	+50.9

Table 50 Construction Employment and Value of Construction Contracts Awarded in the Gulf Coastal States, 1972

State	Employment	Value of Contracts (Million $)
Texas	252,000	1,651
Louisiana	85,000	2,036
Mississippi	35,000	885
Alabama	57,000	1,355
Florida	204,000	6,522

Table 51 Value All Mineral Production in the Gulf Coastal States, 1972

State	Value (Million $)
Texas	7,300
Louisiana	5,600
Mississippi	256
Alabama	333
Florida	397

Table 52 Total Value of Crude Oil, Natural Gas Liquids and Natural Gas, and Percent of Value of All Mineral Production in the Gulf Coastal States, 1973

State	Value (1,000 $)	% of All Mineral Production
Texas	7,829,922	92.4
Louisiana	5,594,712	95.7
Mississippi	238,673	85.3
Alabama	46,653	8.6
Florida	170,563	14.9

Table 53 Number of Employees in the Crude Oil and Natural Gas Industry, 1973, by State

Texas	100,979
Louisiana	49,400
Mississippi	4,900
Alabama	3,387
Florida	1,036

Table 54 Agricultural Economy in the Gulf Coastal States

	Texas	Louisiana	Mississippi	Alabama	Florida
Farm Population					
1960	694,500	233,100	543,000	402,855	105,000
1970	472,000	171,000	261,000	222,196	150,000
% Change	-32.0	-26.6	-51.9	-44.8	+42.9
Total Cash Farm Receipts (Million $)					
1962	2,575	448	704	573	899
1972	4,462	882	1,210	988	1,681
% Change	+73.3	+96.9	+71.9	+72.4	+87.0

The following table contains the historical and projected population and employment data for the three sections of the Gulf of Mexico region, as delineated by the Bureau of Economic Analysis Economic areas adjacent to the Gulf area.

Table 55 Historical and Projected Population and Employment, by BEA Regions and the U.S.

Region	1950	1970	% Change 1950-1970	1990	% Change 1970-1990
Eastern Gulf					
Population	1,698,259	3,267,717	92.4	4,732,900	44.8
Employment	600,384	1,138,419	89.6	1,704,200	49.7
Central Gulf					
Population	2,070,014	2,900,230	40.1	3,142,900	8.4
Employment	692,826	963,028	39.0	1,186,500	23.2
Western Gulf					
Population	3,140,093	4,883,064	55.5	6,078,000	24.5
Employment	1,133,386	1,816,283	60.3	2,535,700	39.6
United States					
Population	151,236,648	203,857,864	34.8	246,039,000	20.7
Employment	57,474,912	79,306,527	38.0	106,388,000	34.1

Source: 1972-E OBERS Projections (Volume 5), U.S. Department of Commerce.

As indicated on the table, all three sections of the Gulf region had a higher percentage increase in population and employment than the U.S. as a whole during the 1950-1970 period. However, during the period from 1970 to 1990, the population and employment in the Central Gulf section is expected to be lower than the U.S. average increase, and the Western Gulf section is expected to be only slightly higher than the U.S. as a whole.

(9) Commercial Fisheries in the Gulf of Mexico Region

In 1973, the United States' commercial harvest of finfish, shellfish and other aquatic life amount to 4.7 billion pounds, worth a record $907.4 million to the fishermen. Commercial landings in the Gulf of Mexico accounted for 32.7 percent or 1.5 billion pounds of the total U.S. catch volume and 29.6 percent or $268 million of the total U.S. catch value. Table 56 below indicates the volume and value of commercial landings in the Gulf region in 1972 and 1973.

Overall production for the Gulf was lower in 1973 than the previous year. The primary factor causing the decrease was the tremendous influx of fresh water into the Gulf, and bays and sounds of the upper Gulf. A secondary factor was the below normal water temperature through late spring.

Shrimp, which accounted for 72.7 percent of the value of all fishery products landed from the Gulf for 1973 (Table 57), were the most severely affected by these adverse conditions. Statistics released by the U.S. National Marine Fisheries Service showed that shrimp landings were off 30 percent in Louisiana, 55 percent in Mississippi, 15 percent in Texas, and 31 percent in Alabama for 1973. Landings in Florida were up 12 percent due to the increase in catch of pink shrimp on the Dry Tortugas grounds.

Table 56 Gulf of Mexico Commercial Landings, by States, 1972-1973*

	1972							
	Thousand Pounds	%	Thousand Dollars	%	Thousand Pounds	%	Thousand Dollars	%
Alabama	39,564	2.5	18,326	8.2	39,749	2.6	18,080	6.8
Florida (Gulf)	97,422	6.1	36.269	16.2	99,200	6.4	43,462	16.2
Louisiana	1,070,597	67.6	71.916	32.2	1,035,959	66.9	98,446	36.7
Mississippi	260,216	16.4	11,897	5.3	271,594	17.6	16,887	6.3
Texas	117,000	7.4	85,011	38.1	100,969	6.5	91,271	34.0
TOTAL GULF	1,584,799	100.0	223,419	100.0	1,547,471	100.0	268,146	100.0

* Landings in interior waters estimated, except Florida; all landings for 1973 are preliminary.

Source: National Marine Fisheries Service, U.S. Department of Commerce, and O. B. Lynam, Texas Parks and Wildlife Service, Seabrook, Texas.

Table 57 Preliminary Landings by Species for the Gulf of Mexico, 1973

	Million Pounds	%	Thousand Dollars	%
Shrimp	203.0	13.1	195,000	72.7
Menhaden	1,100.0	69.3	44,000	16.6
Oysters	14.9	1.0	9,646	3.6
Crabs	42.9	2.8	5,264	2.0
Red Snapper	8.2	0.5	5,020	1.9
Other	----	13.3	---	3.2

Source: National Marine Fisheries Service, Department of Commerce, Washington D.C., and O. B. Lynam, Texas Parks and Wildlife Service, Seabrook, Texas.

Based on 1972 statistics, brown shrimp (*Penaeus aztecus*) comprised 64 percent of the catch, white shrimp (*P. setifeus*) 29 percent, and pink shrimp (P. duorarum) 7 percent. Minor catches of sea bob (*Ximphopeneus kroyeri*) and the deepwater royal reds (*Hymenpenaeus robustus*) were also reported, but accounted for less than one-half of one percent of the catch.

Menhaden, the second leading fishery behind shrimp in value, represented the largest catch by volume in the Gulf region. Louisiana and Mississippi were the leading Gulf States in menhaden, respectively. Together with shrimp, these two categories represented 82.4 percent of the catch and 89.3 percent of the total value of the Gulf fisheries (Table 57).

In 1973, menhaden landed on the Gulf was off about 5 percent and oysters were also down. Crab catches were above normal for the Gulf in 1973.

The table below indicates the 1973 ranking of the Gulf region states by volume and value in the total United States commercial fishery.

Table 58 Ranking of Gulf States in Total U.S. Commercial Landing, 1973

	Catch Volume	Catch Value
Louisiana	1	3
Mississippi	5	15
Texas	12	4
Florida (Gulf)	13	9
Alabama	17	16

Other marine species taken commercially in the Gulf of Mexico are listed below, from information provided by the U.S. Department of Commerce, National Marine Fisheries Service.

FINFISH

- Amberjack
- Angelfish
- Ballyhoo (halfbeak)
- Bluefish
- Blue runner or hardtail
- Cobia (ling)
- Crevalle (jacks)
- Croaker
- Dolphin
- Drum:
  - black
  - sea
- Flounders
- Groupers
- Grunts
- Hogfish
- Jewfish
- King Mackerel
- King whiting (kingfish)
- Mullet:
  - black
  - silver
- Permit
- Pigfish
- Pompano
- Sand perch (mojarro)
- sea bass
- sea catfish (gafftop)
- Sea trout:
  - gray
  - spotted
  - white
- Sharks
- Sheepshead, saltwater
- Snapper:
  - lane
  - mangrove
  - mutton
  - vermilion
  - white
  - yellow tail
- Spanish mackerel
- Spot
- Tenpounder (ladyfish)
- Tilefish
- Triggerfish
- Tripletail (blackfish)
- Warsaw grouper
- Red (redfish)

SHELLFISH

- Spiny lobsters
- Squid
- Stone crabs
- Spanish lobster
- Conchs
- Sunray venus clams

OTHER

- Terrapin
- Turtles, sea
- Sponges
  - grass
  - sheepwool
  - yellow

(10) Oil and Gas Resources, Gulf of Mexico Region

The following estimates of oil and gas resources in coastal State waters are provided by the U.S. Geological Survey. USGS emphasizes that the estimates are speculative; only the maximum credible expectations are shown.

Table 59 Current (1972) Oil and Gas Production from Coastal State Waters

(Oil in billion barrels; includes natural gas liquids)
(Gas in trillion cubic feet)

Area	Oil	Gas
Eastern Gulf	0	0
Central Gulf Western Gulf	0.1	0.6

Table 60 Estimates of Undiscovered Recoverable Resources in Coastal State Waters*

(Oil in billion barrels; includes natural gas liquids)
(Gas in trillion cubic feet)

Area	Oil	Gas
Eastern Gulf	0-2	0-10
Central Gulf	0-2	0-10
Western Gulf	0-2	0-10

---

* On March 26, 1974, the U.S. Geological Survey released estimates of the undiscovered recoverable oil and gas resources for broad areas of the OCS. Those estimates were based on statistical parameters of oil occurrences that apply only to broad geographic areas. It is entirely inappropriate to apply the same parameters to small, specific areas. The resource figures in the above table represent a general estimate, based on the above referenced information, of minimum and maximum volumes of oil and gas that might be recovered from the various OCS areas. It is statistically unsound to add the maxima and minima for an expectable range of resources for any larger area. New estimates have recently been prepared by the USGS for the undiscovered recoverable resources in OCS areas, and are discussed previously in the Description of the Proposed Action.

Table 61 Measured and Inferred Reserves in Coastal State Waters
(December 31, 1972 Estimate)

(Oil in billion barrels; includes natural gas liquids)
(Gas in trillion cubic feet)

Area	Measured Reserves		Inferred Reserves	
	Oil	Gas	Oil	Gas
Eastern Gulf	0	0	0	0
Central Gulf	0.5	6.5	0-0.5	3-5
Western Gulf				

The oil and gas resources in the Gulf Coastal States onshore area are vitally important to supplying the U.S. energy demands. The table below indicates the 1973 production in the five states.

Table 62 Petroleum Production in the Gulf Coastal Region, 1973

State	Crude Oil & Natural Gas Liquids (Thousand barrels)	Natural Gas (Million Cubic Feet)
Texas	1,596,248	8,240,478
Louisiana	966,643	8,457,596
Mississippi	55,010	96,657
Alabama	11,671	7,892
Florida	32,930	33,660

Source: American Petroleum Institute and American Gas Association.

d. Existing Environmental Quality Problems in the Coastal Zone

(1) Water Quality

Florida[1] - Domestic pollution is greatest in the Tampa Bay system and industrial pollution is greatest in the northern estuaries. In a 1971 study, 402 sources of pollution were identified along the Florida Gulf Coast. In the study it was estimated that polluted areas make up 31% of the area of all west coast estuaries. If Florida Bay is excluded, then the polluted area amounts to 43% of the total estuarine area. Ten of the estuarine areas strongly affected by pollution are: Caloosahatchee River, Sarasota Bay system, Hillsborough Bay, Old Tampa Bay, Boca Ciega Bay, Fenholloway River, St. Joseph Bay, St. Andrew Bay, Escambia Bay, Pensacola Bay, and Perdido Bay.

Besides bacterial levels, very few studies on other pollutants have been done for Florida's Gulf Coast. In 1970 Tampa Bay was polluted by 5,000-10,000 gallons of Bunker C fuel oil, causing considerable damage to seabirds and beaches, but no long-term results of this spill have been reported. Minor oil spills have occurred in Pensacola Bay and St. Joseph Harbor.

---

[1] Sources of Information: McNulty, Lindal, and Sykes (1972), Stursa (1973), Taylor (1970).

Alabama[1] - Water quality degradation in the Mobile Bay area is primarily the result of municipal and industrial discharges from sources in Mobile. Sewage outfalls from commercial development along the Alabama Gulf Coast are minor and result in only localized water quality degradation.

There were 23 sources of domestic pollution in Mississipi Sound, Mobile Bay and the Mobile River Delta in a July 1970 inventory. The effluent from 19 of these sources averaged over 25 million gallons per day, and the amount of treatment ranged from untreated to a high degree of secondary treatment. Unknown amounts of domestic sewage also enter the waters from ships, septic tanks, seafood processing plants and other sources. This has resulted in the permanent closing to shellfishing of about 28% of Mobile Bay.

Waters of Mississippi Sound, Mobile Bay and its rivers receive discharges from more than 30 industrial plants (July 1970 inventory). The average daily effluent from 16 of these sources was over 800 million gallons with two major paper mills being the largest contributors. The effects of these industrial effluents upon the marine biota and environment have apparently not yet been assessed.

---

[1] Sources of Information: Crance (1971); Stursa (1973), Swingle (Unpub. Rep. of Ala. Mar. Resources Lab, 1972).

Mississippi[1] - At the present time there seem to be two main areas where the pollution problems are of major concern. The first of these is in the area around Pascagoula and Escatawpa, where pollution is due primarily to heavy concentration of industry in the area.

The second area of major concern is the area in and around Biloxi and Gulfport. The pollution problems here are attributed mainly to inadequately or poorly treated human waste and to small seafood processing plants. This area is heavily populated and the waste treatment facilities apparently cannot adequately handle the generated wasteloads.

Louisiana[2] - Water quality of the coastal waters and rivers of Louisiana generally varies as to location and season of the year. Rivers east of the Mississippi within Louisiana generally have good water quality while lakes and bays (especially Lake Pontchartrain have poorer quality waters. Even poorer water quality is encountered in the Mississippi River. West of the Mississippi River, water quality conditions are generally considered good except in the Lower Calcasieu River and parts of Calcasieu Lake and the Sabine-Neches complex.

---

[1] Source of Information: Barry S. Royals, Mississippi Air & Water Pollution Control Commission, Personal Communication.

[2] Source of Information: Report on Gulf Coast Deepwater Port Facilities. Appendix F Environmental Assessment Central Gulf, DOA Corps of Engineers. June 1973.

Industrial wastes emptying into the Louisiana coastal waters were estimated by Perret et al. (1971) at approximately 1,440 million gallons per day. Greatest discharges were into the Mississippi and Calcasieu Rivers. This is due to the extensive oil-chemical processing plants located in proximity to them. Other sources of industrial discharges include sugar refineries, fish processing plants, electrical generators and meat processors. In general, water quality is not seriously deteriorated by industrial discharges along the Louisiana coast other than in the above-mentioned rivers.

Texas - Water quality degradation occurs from sewage and industrial pollutions, dredging operations, pesticides, urban and agricultural runoff, changes in hydrological regime, shipping, offshore oil operations, etc.

The Corps of Engineers reviewed the water quality problems along the Texas coastline in preparation of a report on Gulf coast deepwater port facilities (U.S. Army Corps of Engineers, 1973). Some of their findings are included below.

Areas of moderate to heavy pollution are shown in Figure 76 . Pollution levels are high in the Houston Ship Channel, along the west side of Sabine Lake and up the Neches and Sabine tidal estuaries. Pollution levels are also high in the area surrounding the city of Galveston and in a small area near a chemical plant in Lavaca Bay. Other small

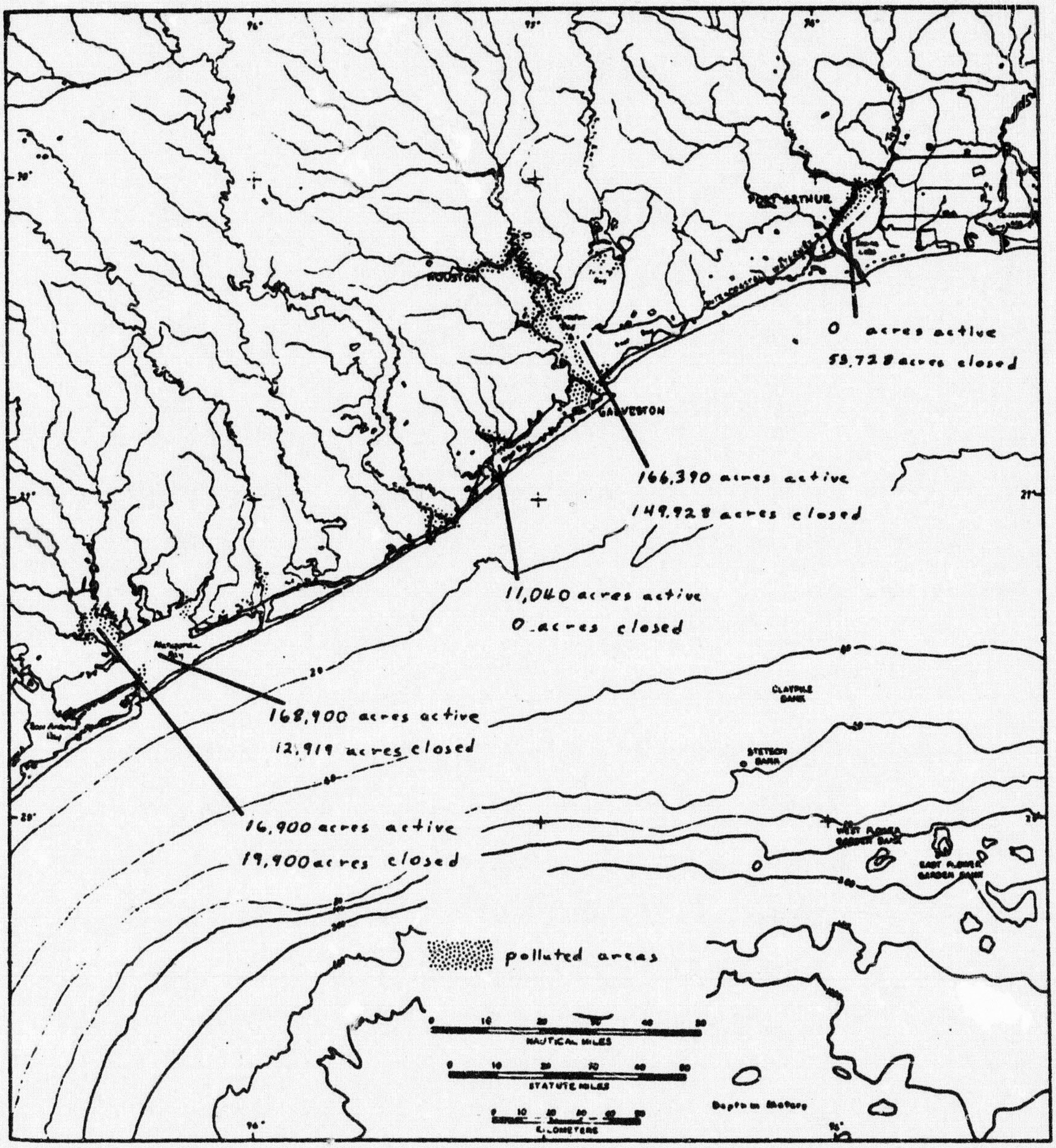

PORT ARTHUR
HOUSTON
GALVESTON
Matagorda Bay
0 acres active
53,728 acres closed
166,390 acres active
149,928 acres closed
11,040 acres active
0 acres closed
168,900 acres active
12,919 acres closed
16,900 acres active
19,900 acres closed
CLAYPILE BANK
STETSON BANK
WEST FLOWER GARDEN BANK
EAST FLOWER GARDEN BANK
polluted areas
NAUTICAL MILES
STATUTE MILES
KILOMETERS
Depths in Meters

Figure 76 Areas of Moderate to Heavy Water Pollution in eastern Texas Bays and Estuaries. Areas of closed and approved (active) oyster reefs are indicated. (from U.S. Army Corps of Engineers, 1973).

areas of pollution are located in tributaries of most of the bays located near oil fields, where the disposal of oil field brines takes place.

In the bays, oyster reefs reflect areas of human disturbance because they are closed to harvesting when bacterial counts or incidents of hepatitis are too high. As of September 1, 1970, the Texas Department of Health had closed virtually all reefs in the Sabine Lake, almost half the reefs in Galveston Bay and over half the reefs in Lavaca Bay, representing most of the bays with significant oyster production. Acreages of closed and active reefs are indicated in Figure 76 .

Large-scale ocean dumping operations in the Gulf of Mexico began in 1952. Since that time, ocean disposal of various materials has occurred at one time or another at 56 different sites. Most of these locations were used for dredge spoil disposal. In 1973, EPA approved 14 interim dump sites in the Gulf. Twelve of these sites, located off the western Louisiana-east Texas coast, were classified as dredge spoil sites and the remaining 2, in deep water (800 meters) beyond the shelf, as chemical disposal areas.

During a six-month period (May-October, 1973), about 7,870 metric tons per month of assorted chemical wastes were discharged directly into Gulf waters at the western disposal site. During this same period, an average 600 metric tons per month of containerized chemical wastes were discharged at the eastern site.

(2) Air Quality

Texas: Because of the high concentration of population and industry, and the unique meteorology of the area, the Texas coastal region has a high potential for the occurrence of air pollution problems (Classen, 1970). The City of Houston and the high concentration of industries along the Houston Ship Channel are the two most critical air pollution locations in the zone. In addition there are numerous other locations in the coastal zone in which frequent air pollution episodes endanger the health and well-being of the public; the Beaumont-Port Arthur-Orange areas, and the Corpus Christi area being of particular concern.

The weather along the Texas coastal zone greatly affects the air pollution problem. The moisture in the air may react with some of the gaseous pollutants to form such pollutants as sulfuric and nitric acid mist which eventually settles to the ground. However, the large amount of precipitation, which is characteristic throughout most of the Texas coastal zone, periodically flushes the air of most contaminants. The prevailing southerly winds from the Gulf of Mexico aid in dispersing many of the high air pollution concentrations.

Louisiana: Air quality over most of Louisiana is good, being better than ambient air quality standards in all but a few areas around heavy industrial complexes. Air quality is poorest in the Baton Rouge area near the heavy industrial complexes north of the city; suspended particulates, dustfall, sulphur dioxide and hydrocarbons exceed ambient standards. At the other stations, Lafayette, Lake Charles and New Orleans, only suspended particulates consistently exceeded ambient standards during several months during 1971.

Mississippi-Alabama-Florida: Air quality in the coastal zones of these states is generally good. Notable exceptions however, are the Pascagoula area, the Mobile area, and the Tampa-St. Petersburg area.

Air quality in the offshore regions of the Gulf is generally good, however local degradation is evident adjacent to highly developed coastal regions, especially the heavily-industrialized areas of the Texas coast.

(3) Dredging

Deterioration of the environment by dredging can result from removal of benthos and benthic habitat in the path of the dredge, turbidity of the water and burial of the benthic community where the spoil is discharged, loss of aquatic habitat by emergent spoil banks and fingerfill real estate development, alteration of natural drainage and tidal patterns by deep channels and spoil banks, erosion and saltwater intrusion in wetland areas, and resuspension of toxic materials previously buried in sediments. Dredging is carried out for several purposes: landfill operations, creation and maintenance of navigation channels and canals, sand and shell dredging, and pipeline laying.

Florida: The rise in boat registrations in Gulf coast counties, up more than 1000% from 1960 to 1970, has resulted in a demand for marinas and channels to accommodate navigation and anchorage.

About 20% of Boca Ciega Bay has been destroyed by dredge-fill development. As a result, the normal pattern of tidal circulation has been drastically changed and an enormous volume of silt and clay has been redeposited in a natural basin north of the Pinellas County Bayway, and in the access canals between fingerfills. The dredged area and the area where material was placed were effectively lost as habitat, the dredged channel was generally too deep for regrowth of marine grasses, and spoil areas were inundated.

Statewide, as of 1967, of 796,000 acres of original estuarine habitat, 59,700 acres have been lost to dredging. In addition, another estimated 23,521 acres of Florida's Gulf Coast had been filled by housing, industry and other development through 1967.

Alabama: The most harmful dredging project in Alabama has been the Mobile Ship Channel, which, along with its spoil banks has seriously altered circulation and sedimentation patterns within the bay. Apparently, above average rates of sediment accumulation are occurring in the southwestern portion of Mobile Bay. The effects of dredging on aquatic animals in the Mobile Bay system have been investigated on at least two occasions; the investigators observed no adverse effects in either case, although chronic oxygen depression may be the result of such dredging activity.

Mississippi: The lack of large urban areas on the Mississippi Gulf coast has kept the need for filling marshland to a minimum. Dredging of channels and maintenance of "Gold Coast" artificial beaches have been done at intervals, but very little has been reported with regard to biologically harmful effects of this dredging.

Pipelines have been laid across Mississippi Sound from coastal Louisiana oil fields to the Pascagoula refineries.

Louisiana: The principal dredging operations in Louisiana are for canal operations associated with the oil and gas industry, dredging to maintain navigational channels and dredging for oyster shell. It has been estimated that approximately 2.15 sq. miles of marsh are lost each year as a result of the petroleum industry activities. [1] In addition to this dredging, constant effort must be exerted to maintain channels especially at the mouth of the Atchafalaya River and at the southwest pass of the Mississippi River. Dredging requirements have recently increased 3 to 4 times over normal in these areas. [2]

Texas: Because of the extremely shallow character of the Texas bays, considerable dredging has taken place in order to construct navigation channels for commerce and industry located in the coastal sea ports. The Intracoastal Waterway extends the entire length of the Texas coast and is the mainstay of coastal inter- and intrastate cargo transportation. Considerable amounts of emergent spoil and land fill has been created in each of the bay systems, and especially in Galveston Bay.

1/ Louisiana State University, Coastal Studies Institute, "Geologic and Geomorphic Aspects of Deltaic Processes, Mississippi Delta System", Baton Rouge, La., 1970.

2/ Remarks by General Charles C. Noble, U. S. Army Corps of Engineers, Mississippi Academy of Science Meeting, Biloxi, Mississippi, 22 March, 1974.

3. Pacific Region (and Sub-Areas)

a. Geology

The geology of the nearshore and coastal zone has been described previously in the discussion of the offshore environment (section II A.3.a) since unlike biological and some other physical parameters, geologic structures are not commonly distinguished according to an arbitrary division based on water depth or proximity to the shoreline. Where specific geologic structures are unique to a nearshore area, they are noted as such.

b. Biological Environment and Communities of the Coastal Zone

This section will be divided into the following subheadings: (1) terrestrial communities, (2) intertidal, and (3) bays and estuaries.

(1) Terrestrial Communities

The terrestrial areas of the coastal zone can be sub-divided into three major communities or biomes. The vast majority of the coastal zone south of Point Conception, California is urbanized and has lost its natural vegetative community structures. Grassland biomes are present but rare around Point Conception, Morro Bay, and Point Reyes, California. The woodland-bushland biome occupies the remaining non-urbanized coastal area of California south of Sonoma County. Continuing to the Canadian Border, nearly all the remaining coastal area consists of the coniferous forest biome (U.S. Dept. of Interior, 1973f). Table 63 lists representative fauna of these three biomes.

Because the woodland-bushland biome is so widespread, a wide variety of vegetation and wildlife occurs. However, no one species is unique to any one vegetation type or representative of the biome. The dominant mammal of the biome is the deer.

The most extensive biome along the Pacific coast (north of San Francisco) is that of the coniferous forest. At the more southern part of the biome animals are similar to those in the woodland-bushland biome.

There are relatively few species of fish in this area, but nearly all of the streams of any size have good populations of anadromous fish such as steelhead, shad, coho, and chinook salmon.

(2) Intertidal

Areas having rocky shores or rocky outcrops on otherwise sandy beaches have a larger and more diverse intertidal community than sandy beaches. The total area comprising the rocky intertidal habitat varies seasonally. The heavy surf during the winter greatly increases the amount of rocky shores as it washes much of the sand away from the beaches. The movement of sand is important to the state of the rocky intertidal community. It can smother existing intertidal organisms, interfere with spawning and larval activities, and change the amount of available rocky shore. The relative duration of tidal exposure is another important aspect of the rocky shore intertidal community. Because of the degree of tidal exposure, the community may change over a vertical distance of only several feet.

TABLE 63

REPRESENTATIVE FAUNA OF THE THREE MAJOR BIOMES OF THE PACIFIC COASTAL ZONE

(a) Woodland-bushland Biome

California mule deer
Blocktailed deer
Cougar
Black bear
Coyote
grey fox
spotted and striped skunk
jackrabbit
ground squirrel
pocket gopher
raccoon
grey squirrel
opossum

Hawks
Vultures
Quail
Pigeons
Jays
magpirs
owls

Fence Lizard
rattlesnake

Trout
warm water game fish

(b) Grassland Biome

As above, Woodland-bushland biome, except fewer deer, no black bears or cougar, and a greater variety of rodents and burrowing animals.

(c) Coniferous forest biome

As above, Woodland-bushland biome, except the presence of Roosevelt elk, martin, fisher, flying squirrel, mountain beaver, blue grouse, horned and spotted owls, sharp-skinned hawks, and garter snakes.

The force of the waves on stretches of completely open coast is so great that animals up near the high-tide line are wetted by spray on all but the lowest tides. Consequently, there is not the relatively sharp zonation found elsewhere and some of the most obvious animals are fairly well distributed throughout the intertidal zone. Ricketts, Calvin and Hedgpeth (1968) described the vertical zones (spray, high tide, mid-tide and low tide zones) of the intertidal exposure and habitats within them.

The species composition of the attached algae changes with the latitude and temperature of the Pacific coast (Ricketts, Calvin and Hedgpeth, 1968; Allan Hancock Foundation, 1965). Each geographic region has similarly adapted species, typically of the same genus. The assemblage of *Mytilus californianus* (mussel), *Pollicipes polymerus* (stalked barnacle) and *Pisaster ochraceus* (ocher seastar) is characteristic of exposed beaches. On semi-protected beaches the mussel *M. edulis* is characteristic.

The extent and distribution of rocky shores on the Pacific coast is summarized as follows. South of Point Conception, California about

20% of the shoreline is rocky shore. North of this point, there is an increase in the amount of coastline having rocky shores. Monterey and Sonoma Counties have over 75% rocky shores. In Humboldt and Del Norte Counties the relative amount of rocky shores decreases to 30 to 40% (California Dept. of Fish and Game, 1973).

According to the U.S. Army Corps of Engineers (1971) southern Oregon has approximately the same amount of rocky shores as northern California (30 or 40%) for the first 50 miles of coastline. Proceeding northward, with the exception of an extensive rocky shore around Otter Rock in Lincoln County, rocky shores are rare, comprising less than 10% of the shoreline. This holds true for the Washington coastline except the extensive rocky coast around Cape Flattery near the Strait of Juan de Fuca. Much of the Oregon and Washington coastline is backed by sea cliffs, however, and many of the short pocket beaches are transformed into rocky areas during the winter.

The dominant species include: Orchestoidea californiana (sand hopper, an amphipod crustacean); Emerita analoga (sand crab); Donax gouldii (surf clam); Tivela stultorum (Pismo clam). The grunion Leuresthes tenuis (a fish) utilizes sandy beaches for spawning during night-time spring tides between March and August.

Increasing in importance in the Pacific Northwest (also present in parts of California) are butter clams, littlenecks, manila, cockles, geoducks, and horseclams. The most numerous northern clams are razor clams (Siliqua patula) (Washington Dept. of Natural Resources, 1972).

(3) Bays and Estuaries

Largely reflecting the gradual northward increase in rainfall and consequent river discharge volume in northern latitudes there is a general trend for the size of estuaries and their importance to the coastal marine environment to increase. Many of the small bays in southern California are fed by intermittent streams and actually lose free communication with the ocean during the summer dry period. In contrast to this is the Columbia River Estuary with a fresh water flow of from 15,000 to 600,000 cu. ft./sec. (Neal, 1972) which lowers the ocean salinity for a distance over 100 miles from shore (Barnes, et al, 1972).

There are exceptions to the above generalization regarding the size of estuaries. The nearly 14,500-acre San Diego Bay, though of substantial size, has lost most of its wildlife habitat through construction activity. The loss of natural estuarine areas is widespread in this country, but is particularly extensive in Southern

California. According to the U.S. Fish and Wildlife Service (1972), at the beginning of this century there were 28 sizeable estuaries between Morro Bay, California, and Ensenada, Mexico. Since that time 15 have been modified either slightly or moderately, 10 have been altered drastically, and 3 have been destroyed.

California's coastal wetland and estuarine acreage is about 422,000 acres--less than one-half of one percent of the State's land area. Only about 31,700 acres of this is in Southern California, from Morro Bay south to the Mexican border. This is just 25% of that which existed in 1900. Less than 13,100 acres are marshlands and tidelands. The remaining 18,500 acres are open water.

San Francisco Bay, the largest estuary in California, remains the center of estuarine fishing activities for the State (Frey, 1971) in spite of its grossly polluted and altered condition, as studies by Filiece (1954, 1959) have demonstrated.

California estuaries are important to the life cycle of many important fishes, and are the habitat of the following sport and commercial shellfish: ghost shrimp, littleneck clam, gaper clam, Washington c[illegible] oysters, bay shrimp, and market (Dungeness) crab (Frey, 1971).

Oregon has about 14 estuaries, the largest of which are the Columbia River Estuary (15,000 acres), Coos Bay (9,543 acres), Tillamook Bay

(8,839 acres) and Umpqua-Winchester Bay (5,712 acres) (Oregon State Univ. Advisory Program). Washington, counting the Columbia River Estuary which is shared in common with Oregon, has the largest estuaries on the Pacific Coast. The most important are Willapa Bay (34,871 acres), Grays Harbor (7,150 acres) and the gigantic Puget Sound (about 1.3 million acres).

Fishery resources of Washington and Oregon estuaries include salmon, clams, (gaper, cockle, softshell, butter and littleneck), oysters, and several species of shrimp and crabs. As with California, there are fin fish taken in the estuaries which also inhabit the oceanic areas.

The extreme importance of estuaries as nursery areas and as nutrient and organic contributors to the oceanic coastline has been discussed in the Atlantic and Gulf of Mexico sections, and will not be elaborated here.

c. Resources of the Coastal Zone

(1) Land Characteristics

Pacific Coast Region

The Pacific Coast region consists of the coastal zone of the conterminous United States--California, Oregon and Washington, which has been divided into five sections as shown on Figure 77 .

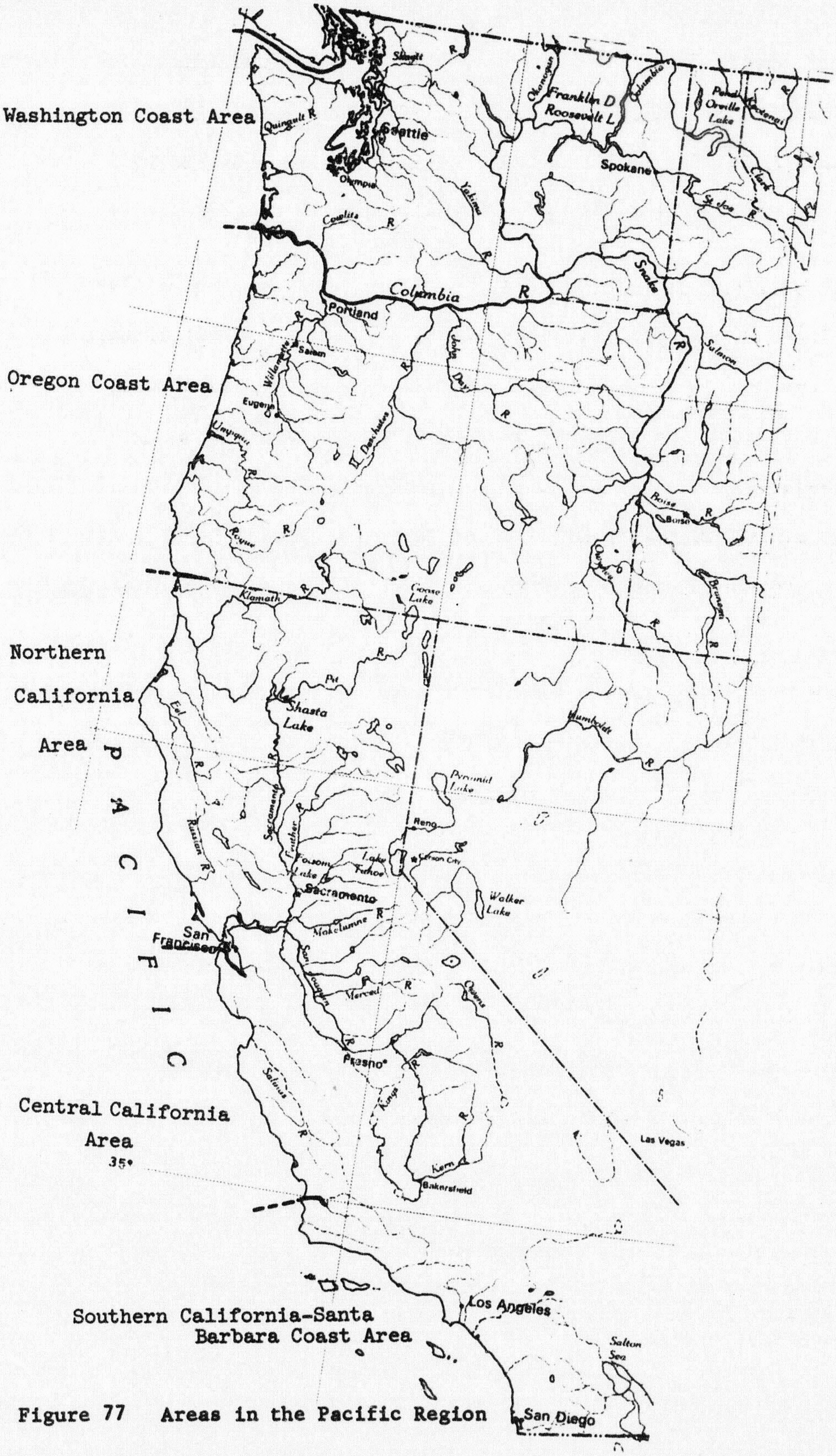

Washington Coast Area
Oregon Coast Area
Northern California Area
Central California Area
35°
Southern California-Santa Barbara Coast Area
PACIFIC
Skagit R
Quinault R
Seattle
Olympia
Cowlitz R
Yakima
Okanogan
Franklin D. Roosevelt L.
Columbia
Pend Oreille Lake
Kootenai
Spokane
Clark
St. Joe R
Snake
Columbia R
Portland
Salem
Willamette
Eugene
Umpqua
John Day
Deschutes
R
Salmon
R
Boise
Boise
R
Owyhee
Bruneau
Rogue R
Klamath R
Goose Lake
Pit R
Shasta Lake
Eel
R
Humboldt
R
Pyramid Lake
Reno
Carson City
Lake Tahoe
Walker Lake
Sacramento
Feather
Russian R
Folsom Lake
Sacramento
Mokelumne R
San Francisco
San Joaquin
Merced R
Owens
R
Fresno
Salinas
R
Kings
R
Kern
Bakersfield
Las Vegas
Los Angeles
Salton Sea
San Diego

Figure 77 Areas in the Pacific Region

Data for this region has been adapted in part from the National Shoreline Study--California Regional Study and the National Shoreline Study--Inventory Report--Columbia-North Pacific Region, Washington and Oregon, prepared by the U.S. Army Corps of Engineers (1971).

The Southern California-Santa Barbara Coast area includes the mainland shoreline of San Diego, Orange, Los Angeles, Ventura and Santa Barbara Counties, as well as the offshore islands of San Miguel, Santa Rosa, Santa Cruz, Catalina, San Nicolas, San Clemente, Anacapa and Santa Barbara Islands. The shoreline length of this entire area is 697 miles, and includes the mainland shore of 343 miles, the 275 miles of shore of the offshore islands, and 79 miles of bay and estuary shoreline. The mainland is characterized by three basic shoreline types: gradually sloping flood plains that merge with the ocean; uplifted marine terraces which often have near-vertical bluff or cliff faces that are fronted by beaches of varying width; and steep, rugged mountains with rocky headlands directly on the ocean front.*

Beaches comprise nearly half the total shoreline length of the entire area, as shown on the following table. However, the mainland shore is over 80% beach, much of which is used for recreation. The shoreline of the offshore islands can be generally characterized as having rocky promontories and precipitous cliffs with only occasional pocket beaches. This character is reflected in that only 20% of the shoreline of these islands is beach. The bay and estuary shorelines within

---

* For a generalized portrayal of the coastal landforms of this region and the entire United States, see the National Atlas of the United States "Coastal Landforms" Map, Scale 1:7,500,000, pp. 78-79 (1967).

Table 64 Beach Shoreline in the Pacific Coast Region (in miles)

Area	Beach	Total Shoreline	Percent Beach
Southern California-Santa Barbara Coast	339	697	48.6
Central California	110	315	35.1
Northern California	214	821	26.1
Oregon Coast	300	500	60.0
Washington Coast	1,847	2,337	79.0
TOTAL-Pacific Coast Region	2,810	4,670	60.2

this area are marshy and swampy tidal lagoons that to a great extent have been reclaimed and developed. Only 8% of this bay/estuary shoreline is composed og beach.

The Central California Coast area includes the 315-mile coastline of San Luis Obispo, Monterey, Santa Cruz and San Mateo Counties. The shoreline of this area is a mix of sandy beaches backed by marine terraces and rugged seacliffs, and rocky promontories with offshore rocks and reefs. There is proportionately less beach along this central portion than in the Southern California area. Only 35% of the total shoreline is beach in character. Rugged mountain ranges within the Coast Range extend to the shoreline in several portions of the area, producing a rugged coast with considerable scenic attraction backed by rolling hills, precipitous rocky seacliffs and canyon formations.

The Northern California Coast area has a total shoreline length of 821 miles. The area's shoreline zone includes steep mountainous reaches, both sandy and rocky beach areas, wide river valleys and deltas, and lagoons and bays--such as the Tomales Bay and the extensive San Francisco-San Pablo Bay area. Sandy beaches are generally narrow and limited in extent, and are exposed to winds and cold heavy seas. Prominent offshore rocks and pinnacles are natural features of many of the beach areas. Other sandy beach areas are backed by steep or near-vertical seacliffs ranging in elevation from 30 to 300 feet. Of the entire 821 miles of shoreline, only 26 percent is composed of beach. However, along the ocean shoreline proper, beach areas comprise slightly over 40 percent.

The Oregon Coast area has 500 miles of shoreline comprising 352 miles along the Pacific Ocean proper, and 148 miles of bay/estuary coastline. Three hundred miles of the shoreline consists of beach (60 percent), with the remaining consisting of rocky headlands, marsh areas, bulkheads and revetments. Most of the Oregon coast is bordered by mountains, with the Oregon Coast Range extending from the northern portion, and the Klamath Mountains and Siskiyou Mountains along approximately the southern 70 miles.

The Washington Coast area has 2,337 miles of shoreline comprising 157 miles along the Pacific Ocean proper, 144 miles along the Strait of

Juan de Fuca, 89 miles in Grays Harbor, 129 miles in Willapa Bay, 34 miles on the Columbia River and 1,784 miles along the inland waters of Puget Sound and the Strait of Georgia. This coastline length includes the shorelines of 172 significant islands of San Juan Archipelago. Of the total shoreline of Washington, 1,847 miles, or 79 percent, consists of beach.

(2) Land Ownership

As indicated on the accompanying table, although the majority of the shoreline is privately owned within each of the areas within the Pacific coast region, considerable portions of the coastline are also publicly owned. Many lengths of the California and Oregon coastline are State or county-owned and maintained, primarily as recreation areas, discussed later in this section. The Federal Government also maintains several portions of the coastal zone either for military, recreation or wildlife conservation purposes.

In the Southern California-Santa Barbara Coast area, the offshore islands of San Miguel, San Nicolas and San Clemente are owned by the U.S. Navy; Anacapa and Santa Barbara Islands are maintained by the Federal Government as a National Monument. Only Santa Catalina, Santa Cruz and Santa Rosa Islands are privately owned under single or large ownerships. San Miguel's surface resources are administered jointly by the Department of the Interior and the Department of Defense.

On the mainland shoreline, vast areas in the San Diego County area, as well as areas on the Los Angeles-Orange County shoreline, are also owned by the Federal Government, primarily by the U.S. Navy and U.S. Marine Corps. Seventeen miles of shoreline are involved in the extensive Camp Pendleton Marine Corps Base in northern San Diego County. Vandenberg Air Force Base also occupies a vast portion of the Santa Barbara County coast in the Point Arguello area northward to near the San Luis Obispo County line.

Table 65 Land Ownership of the Pacific Coast Region Shoreline

	Total Length of Shoreline	Federal		State/Local		Private	
Area	Miles	Miles	%	Miles	%	Miles	%
Southern California-Santa Barbara Coast	697	198	28.4	167	24.0	332	47.6
Central California	315	28	8.9	79	25.1	208	66.0
Northern California	821	186	22.7	115	14.0	520	63.3
Oregon	500*	83	16.6	158	31.6	238	47.6
Washington	2,337	155	6.6	107	4.6	2,075	88.8
TOTAL-Pacific Coast Region	4,670	650	13.9	626	13.4	3,373	72.2

* Mileage does not total because ownership is uncertain for 21 miles of shoreline.

The Northern California Coast area contains several Federally-owned sections of shoreline totalling nearly 23 percent of the area. These areas are devoted to military facilities and recreation areas. The Department of Defense (particularly the Navy, Army and Air Force) facilities are generally concentrated in the San Francisco Bay area, whereas the Federal recreation areas of Point Reyes National Seashore and Redwood National Park are located on the ocean front.

The Oregon Coast shoreline is dotted with many State-owned recreation areas, particularly from Bandon northward to just south of Tillamook Bay. Federally-owned portions of the shoreline include National Forest areas and Coast Guard facilities. Less than half of the State's shoreline (47.6 percent) is privately owned.

Below the line of ordinary high water, the State has jurisdiction of the shoreline abutting the Pacific Ocean, seaward of the natural vegetation line. The Oregon State Legislature enacted the "Beach Bill" which recognized that over the years the public has made frequent and uninterrupted use of lands abutting the shore of the Pacific Ocean for recreational purposes and that such use has been sufficient to create easements for the public through dedication, prescription, grant or otherwise. The State Highway Commission has been delegated the authority to protect and preserve the rights of the public in the lands described in the Act.

A relatively small proportion of the Washington Coast area is publicly-owned. The Federal Government owns about 155 miles, including the Olympic National Park, various wildlife refuges and military facilities administered by the U.S. Army and Navy. Several Indian Reservations also occupy shoreline areas, as noted in the table below.

TABLE 66

INDIAN RESERVATIONS LOCATED IN THE WASHINGTON COASTAL AREA

Indian Reservation	Location
Lummi	Whatcom County
Swinomish	Skagit County
Tulalip	Snohomish County
Port Gambe	Kitsap County
Puyallup	Pierce County
Squaxin Island	Mason County
Nisqually	Thurston County
Skokomish	Mason County
Lower Elwha	Clallam County
Makah	Clallam County
Ozette	Clallam County
Quillayute	Clallam County
Hoh	Jefferson County
Quinault	Grays Harbor-Jefferson County
Shoalwater	Pacific County
Port Madison	Kitsap County

(3) Land Use

As shown in the table below, considerable portions of the Pacific coast region shoreline remain undeveloped and in a natural state despite the vast urban pockets or belts located along several areas of the coastal zone. The majority of the development is found in southern and central California. Major urban areas are also found on the Columbia River (Portland, Oregon) and on Puget Sound (Seattle). The many beach areas are perhaps the region's single most valuable shoreline natural resource. The recreation potential has been protected in many areas and has been acquired and developed for public interest. Some farming is interspersed throughout the region.

Table 67 Shoreline Use in the Pacific Coast Region
(in Miles)

Area	Public Recreation	Private Recreation	Non-Recreation Development	Undeveloped	Total
Southern California-Santa Barbara Coast	167	66	71	393	697
Central California Coast	61	33	6	215	315
Northern California Coast	204	80	153	384	821
Oregon Coast	205	82	110	103	500
Washington Coast	147	40	77	2,073	2,337
TOTAL-Pacific Coast Region	784	301	417	3,168	4,670

Land use in the Southern California-Santa Barbara Coast area reflects early Spanish settlement patterns and pastoral and cultivating economic activities. The occurrence of flat terrain with productive agriculture areas and a favorable climate made this area more attractive than lands located in the northern portion of the State. Towns and cities developed in the flat valley and basin areas along the coast, near the few coastal embayments located along the shoreline of this area. Agriculture predominates in the coastal valleys, particularly in Ventura County.

The large urban centers in this area are the San Diego metropolitan area, the Orange County-Los Angeles County urban belt, the Oxnard-Ventura complex and the Santa Barbara coastal area. Slightly over 10 percent of this area's total shoreline length is devoted to urban residential and intense industrial-commercial-transportation land uses. However, the most important use of this area's shoreline is beach recreation. Nearly 25 percent of the shore is used for public recreation and another 9.5 percent is used for private recreation. Privately-owned beaches are generally located near the major metropolitan areas and are being relegated to uses other than recreation at a faster rate than other shoreline areas.

The eight Channel Islands reflect the varied land use of this area. Three islands are used as military reservations--San Miguel, San Nicolas and San Clemente--and are essentially undeveloped. Santa Rosa Island and Santa Cruz Island are privately owned; Santa Rosa is operated as a cattle ranch with a small portion under agricultural cultivation. Santa Catalina Island is privately owned and is a world-famous resort area.

Nearly 30 percent of the Central California Coast area's shoreline is used for recreation, both public and private. However, over two-thirds of the shoreline remains undeveloped, much of it in it's natural state. With the exceptions of development occurring in the river valleys, development has taken place along the coast area proper, similar to that in the Southern California area. However, compared to southern California, urban development is relatively limited. Only 6 miles are devoted to residential and commercial-industrial land uses.

The Northern California Coast area contains the intensively developed area along the San Francisco-San Pablo Bay shorelines on the one hand, and the long stretches of completely undeveloped shoreline along the ocean proper northward. Over one-third of the area's total shoreline is devoted to recreation; nearly 25 percent is public and about 10 percent is private. However, public beach areas are more limited in this northern California area than in the lower part of the State. Point Reyes National Seashore occupies an extensive length of shoreline in Marin County and Redwood National Park occupies portions of Humboldt and Del Norte Counties.

The San Francisco Bay area shoreline has been developed for a variety of uses including urban residential, commercial, industrial, transportation facilities and agriculture. Military facilities occupy several extensive areas and have considerable impact on land use within many parts of this vast metropolitan area.

The Oregon Coast area is an extension of the physical features of northern California. Only a narrow strip of land lies between the ocean and the Coast Range, and as a result land use is limited, similar to the northern counties of California. The steep cliffs and bluffs have resulted in development remaining further inland. For the most part, the residential areas are dispersed along the entire coastal area; unlike southern California there are no densely populated areas. About one-fifth of the Oregon shoreline has not been developed in any true sense, and much of the area categorized as private recreation use (82 miles) has little formal development. Military land use along the shoreline is also insignificant in Oregon. Public recreation sites dot the entire coastline, including beaches, parks and historical sites.

Land use by county is shown in the table below.

Table 68 Shoreline Use in Oregon, by Coastal County

County	Total Miles	% Public Recreation	% Private Recreation	% Non-rec. Developed	% Un-developed
Clatsop	59.0	45.8	5.9	37.3	11.0
Tillamook	111.0	37.9	0.9	32.4	28.8
Lincoln	88.0	27.8	27.3	33.5	11.4
Lane	40.0	42.5	27.5	1.3	28.7
Douglas	33.0	66.7	4.5	4.5	24.3
Coos	75.5	41.7	27.8	21.9	8.6
Curry	93.5	44.1	20.6	4.3	31.0
TOTAL-Oregon Coast Area	500.0	41.0	16.3	22.0	20.7

The Washington Coast area has vast sections of undeveloped shoreline (88.7 percent), however, the Seattle-Tacoma metropolitan area is intensely developed with residential and commercial-industrial-transportation facilities. The land use of the ocean shoreline section of Washington does not differ greatly from that of Oregon. The proximity of the Coast Range to the ocean shore limits the area available, and thus most development has occurred between the Coast Range and the more inland Cascade Range. Numerous recreation areas are located along this ocean shoreline in areas of sandy beach. The linear section of the Olympic National Park is also located along the coast shoreline.

Public and private recreation use along the ocean and in Puget Sound, Strait of Georgia and Strait of Juan de Fuca involves the numerous parks, resorts and pleasure-boat moorage facilities available. In the bay/estuary zones, several State Marine Parks provide moorage facilities used extensively by the populations in the adjacent urban areas. The Puget Sound area is influenced to some extent by military land uses, particularly the U.S. Navy and Army. Extensive and highly developed port and industrial complexes are located along the shoreline of the Everett-Seattle-Tacoma area. Refineries are located adjacent to the shoreline in part of the area, with accommodations capable of handling large tankers. The Burlington-Northern Railroad also occupies considerable shoreline lengths. Other manufacturing, processing, and storage facilities located in this area make up a portion of the total 38 miles of developed shoreline of this urban complex.

The table below indicates land use for the coastal counties in Washington.

Table 69 Shoreline Use in Washington, by Coastal County

County	Total Miles	% Public Recreation	% Private Recreation	% Non-rec. Developed	% Undeveloped
Wahkiakum	8	0	0	0	100.0
Pacific	185	25.3	0	0.5	74.2
Grays Harbor	146	19.9	5.5	5.5	69.1
Jefferson	194	8.1	1.1	1.0	89.8
Clallam	156	5.7	0	3.9	90.4
Kitsap	211	2.1	0	1.9	96.0
Mason	174	1.9	13.0	0.6	84.5
Thurston	90	1.2	0	4.5	94.3
Pierce	235	1.4	0	3.8	94.8
King	113	5.9	0	12.4	81.7
Snohomish	43	2.6	0	34.9	62.5
Island	194	2.9	1.8	0.5	94.8
Skagit	127	3.5	2.8	4.7	89.0
Whatcom	102	8.7	0	4.9	86.4
San Juan	359	2.1	0	0.3	97.6
TOTAL- Washington Coast Area	2,337	6.3	1.7	3.3	88.7

(4) Military Uses

Facilities located along the shoreline areas of the Pacific Coast are listed in Table 70 (some of the facilities are not currently active and may be idle or used for other purposes, such as recreation or wildlife conservation).

(5) Recreation Resources

The coastal zone of the Pacific Coast region is one of the major recreation resources of the Western States. Figure 78 shows the distribution of the existing Federal and State recreation areas (National Seashores, parks, monuments, historic sites, etc.). Table 71 following the map, gives the name, location and acreage (where available) of those areas shown. In addition to these areas, throughout the Pacific coast region there are numerous county and municipal recreation areas that have been established for utilization by local populations and tourists alike.

California's beach areas satisfy many of the State's burgeoning recreation demands. The southern portion of California contains a major portion of the suitable sandy beaches, as well as much of the State's population and coastal development. More than 127 million recreation days were spent at the shore during 1970, an increase of

TABLE 70

MILITARY FACILITIES IN THE PACIFIC COAST REGION

Area

Facility

Southern California-Santa Barbara Coast Area

- Border Field Naval Reservation
- Imperial Beach Naval Air Station
- Imperial Beach Naval Radio Station
- Coronado Naval Amphibious Base
- North Island Naval Air Station
- San Diego Naval Air Station
- San Diego Coast Guard Air Station
- San Diego Naval Training Center
- San Diego Marine Corps Recruit Depot
- San Diego Naval Supply Center
- San Diego Naval Pier
- U.S. Navy Athletic Field (San Diego)
- Fort Rosecrans Naval Reservation
- Ballast Point Coast Guard Station
- Point Loma Fleet Anti-Air Warfare Training Center
- Camp Pendleton Marine Corps Base
- Seal Beach Naval Weapons Station
- Long Beach Naval Station
- Fort MacArthur (Army)
- Point Mugu Naval Air Missile Test Center
- Port Hueneme Naval Construction Battalion Center
- Vandenberg Air Force Base
- San Miguel Island Naval Reservation
- San Nicolas Island Naval Reservation
- San Clemente Island Naval Reservation
- Santa Rosa Island Air Force Station

Central California Coast Area

- Fort Ord (Army)
- Hunter-Liggett Army Reservation

Northern California Coast Area

- San Francisco Presidio (6th Army)
- Fort Winfield Scott
- Fort Mason
- Fort Baker

TABLE 70 (cont')

Northern California Coast Area (cont')

Fort Barry
Fort Cronkhite
Alameda Naval Air Station
Moffat Field Naval Air Station
Mare Island Naval Shipyards
Oakland Army Base
Oakland Naval Supply Center
Treasure Island Naval Station Treasure
Skaggs Island Naval Security Group Activity
Coast Guard Port Captains Office
San Francisco Coast Guard Station
Crissey Army Air Field
Bodega Harbor Coast Guard Station
Point Arena Coast Guard Station

Oregon Coast Area

Tongue Point Naval Station

Washington Coast Area

Port Angeles Coast Guard Air Station
Whidbey Island Naval Air Station
Puget Sound Naval Shipyard
Naval and Marine Training Center
Fort Lewis
Fort Lawton
Seattle Naval Air Station
Bainbridge Island Naval Radio Station
Bremerton Naval Annex
Puget Sound Naval Supply Center--Manchester Division
Puget Sound Naval Supply Center--Seattle Division
Keyport Naval Torpedo Station
Bangor Naval Ammunition Depot
Pacific Polaris Missile Facility
Salmon Bay Naval Terminal.

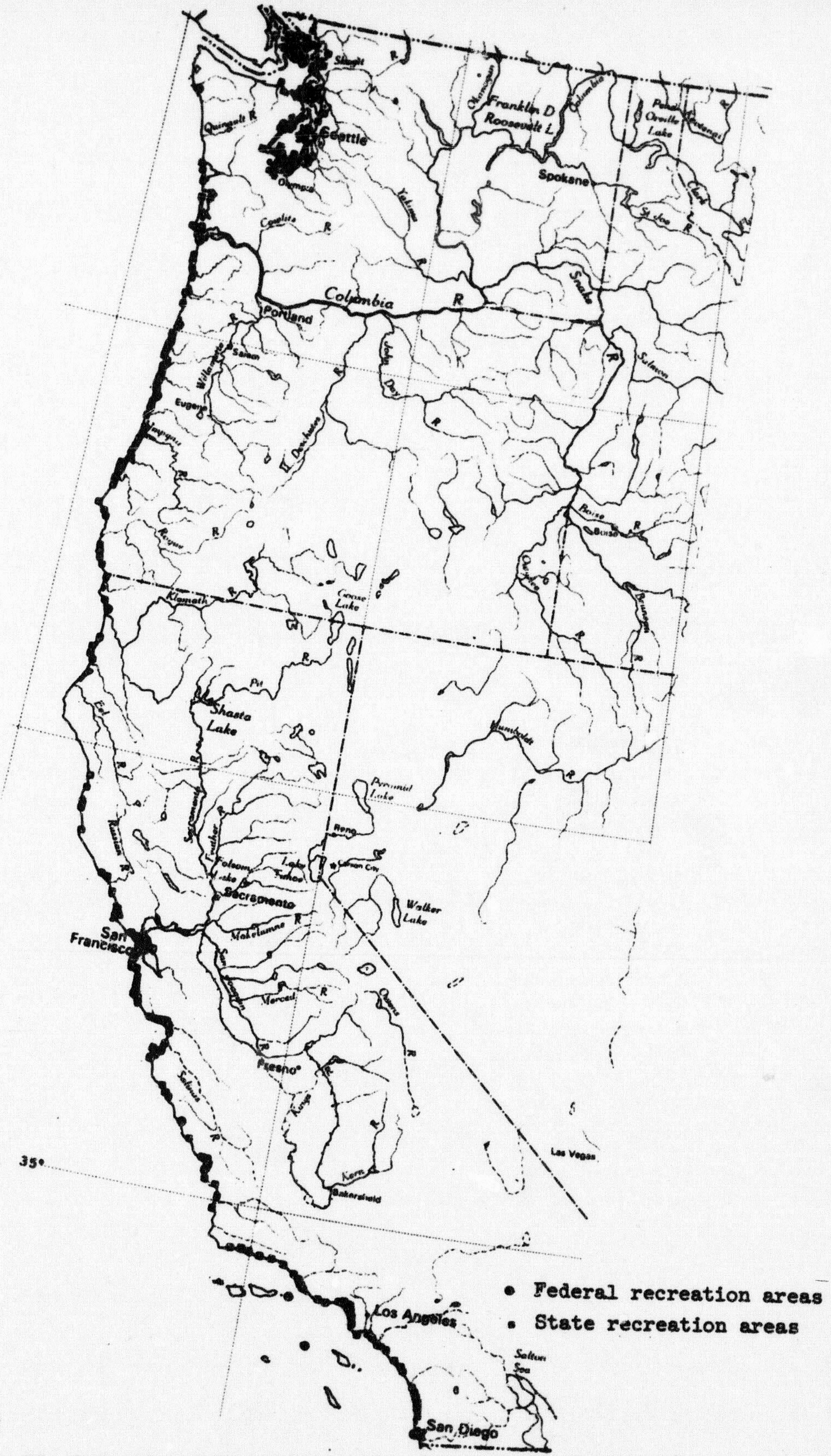

Skagit
Quinault R
Seattle
Olympia
Franklin D Roosevelt L.
Okanogan
Columbia
Pend Oreille Lake
Spokane
Clark Fork
St Joe R
Yakima
Cowlitz R
Columbia R
Snake R
Portland
Salem
Willamette
Eugene
Umpqua
John Day
Deschutes R
Salmon R
Rogue R
Boise R
Boise
Owyhee
Bruneau
Klamath R
Goose Lake
Pit R
Shasta Lake
Eel R
Russian R
Sacramento R
Feather R
Humboldt R
Pyramid Lake
Reno
Carson City
Lake Tahoe
Folsom Lake
Sacramento
Walker Lake
Mokelumne R
San Francisco
San Joaquin
Merced R
Owens R
Fresno
Kings R
Salinas R
Kern R
Bakersfield
Las Vegas
35°
Los Angeles
Salton Sea
San Diego
● Federal recreation areas
▪ State recreation areas

Figure 78 Federal and State Recreation Areas in the Pacific Region

TABLE 71

EXISTING STATE AND FEDERAL RECREATION AREAS

Area Name	Location	Acreage
Southern California-Santa Barbara Coast Area		
Border Field State Park	San Diego County	
Cabrillo National Monument	"	
Silver Strand State Beach	"	428
San Elijo State Beach	"	2,890
South Carlsbad State Beach	"	45
San Onofre Bluffs State Beach	"	2,890
Torrey Pines Beach State Park	"	
Cardiff State Beach	"	
Ponto Beach State Park	"	
Moonlight State Beach	"	
Carlsbad State Beach	"	
San Clemente State Beach	Orange County	110
Doheny State Beach	"	62
Corona del Mar State Beach	"	
Huntington State Beach	"	78
Bolsa Chica State Beach	"	
Royal Palms State Beach	Los Angeles County	
Manhattan State Beach	"	44
Redondo State Beach	"	
Will Rogers State Beach	"	
Malibu Lagoon State Beach	"	
Leo Carrillo State Beach	"	1,578
Dockweiler State Beach	"	
Santa Monica State Beach	"	
Alamitos State Beach	"	
Point Dume State Beach	"	
Las Tunas State Beach	"	
Channel Islands National Monument	Ventura-Los Angeles County	
McGrath State Beach	Ventura County	295
Point Mugu State Beach	"	
San Buenaventura State Beach	"	116
Emma Wood State Beach	"	32
Arroyo Burro State Beach	Santa Barbara County	
Carpinteria State Beach	"	48
Goleta State Beach	"	
El Capitan State Beach	"	111
Refugio State Beach	"	39
Gaviota State Beach	"	2,795
Point Sal State Beach	"	
Los Padres National Forest	"	

TABLE 71 (cont')

Central California Coast Area		
Pismo State Beach	San Luis Obispo County	967
Avila State Beach	"	11
Montana de Oro State Beach	"	6,956
Morro Bay State Park	"	1,478
Atascadero State Beach	"	75
Morro Strand State Beach	"	
Cayucos State Beach	"	25
San Simeon State Beach	"	502
Los Padres National Forest	Monterey County	
John Little State Beach	"	
Pfeiffer-Big Sur State Beach	"	822
Julia Pfeiffer Burns State Beach	"	
Point Lobos State Reserve	"	1,255
Carmel River State Beach	"	
Asilomar State Beach	"	
Monterey State Beach	"	
Salinas River State Beach	"	
Zmudowski State Beach	"	
Manresa State Beach	Santa Cruz County	
Sunset State Beach	"	300
Seacliff State Beach	"	85
New Brighton State Beach	"	64
Capitola State Beach	"	
Twin Lakes State Beach	"	130
Natural Bridges State Beach	"	56
San Mateo State Beach System	San Mateo County	
Ano Nuevo State Beach	"	
Bean Hollow State Beach	"	
Arroyo de los Frijoles State Beach	"	
Pebble State Beach	"	
Pescadero State Beach	"	
Pomponio State Beach	"	
San Gregorio State Beach	"	
Francis-Dunes State Beach	"	
Montara State Beach	"	
Sharp Park State Beach	"	
Thornton State Beach	"	
Half Moon Bay State Beaches	"	
Northern California Coast Area		
Bakers State Beach	San Francisco County	
Seal Rocks State Beach	"	
James D. Phelan State Beach	"	
Golden Gate National Recreation Area	San Francisco-Marin County	
Angel Island State Park	"	740
Marin Headland State Park	Marin County	
Stinson State Beach	"	
Tomales Bay State Beach	"	1,018
Point Reyes National Seashore	"	64,000

TABLE 71 (cont')

Northern California Coast Area (cont')

Alameda Memorial State Beach Park	Alameda County	
Sonoma Coast State Beach	Sonoma County	1,079
Salt Point State Beach	"	3,174
Manchester State Beach	Mendocino County	
Van Damme State Beach	"	1,909
Russian Gulch State Park	"	1,162
MacKerricher State Beach	"	285
Westport-Union Landing State Beach	"	
Little River State Beach	Humboldt County	
Trinidad State Beach	"	159
Patricks Point State Park	"	425
Dry Lagoon State Beach	"	1,036
Redwood National Park	Humboldt-Del Norte Co.	58,000
Del Norte Coast Redwood State Park	Del Norte County	6,375
Pelican State Beach	"	

Oregon Coast Area

Suislaw National Forest	Curry County	622,180
Harris Beach State Park	"	171
Samuel Boardman State Park	"	1,473
Pistol River State Park	"	
Cape Sebastian State Park	"	
Humbug Mountain State Park	"	1,828
Battle Rock State Park	"	
Cape Blanco State Park	"	
Bandon State Park	Coos County	
Bullards Beach State Park	"	1,226
Cape Arago State Park	"	134
Shore Acres State Park	"	683
Sunset Bay State Park	"	395
Umpqua Dunes Scenic Area	"	
William Tugman State Park	"	
Umpqua Lighthouse State Park	Douglas County	2,715
Jessie Honeyman Memorial State Park	Lane County	522
Devils Elbow State Park	"	117
Carl Washburne Memorial State Park	"	1,209
Rockwood Beach State Park	"	
Muriel Ponsler Memorial State Park	"	2
Neptune State Park	"	296
Yachats Ocean Road State Park	Lincoln County	
Beachside State Park	"	17
Governor Patterson Memorial State Park	"	10
Seal Rock State Park	"	
Ona Beach State Park	"	237
Lost Creek State Park	"	
South Beach State Park	"	
Yaquina Bay State Park	"	32
Beverly Beach State Park	"	130
Devils Punchbowl State Park	"	8
Agate Beach State Park	"	

TABLE 71 (cont')

Oregon Coast Area (cont')		
Otter Crest State Park	Lincoln County	
Rocky Creek State Park	"	
Depoe Bay State Park	"	
Fogarty Creek State Park	"	128
Boiler Bay State Park	"	
Cape Lookout State Park	Tillamook County	1,946
Cape Meares State Park	"	
Nehalem Bay State Park	"	890
Oswald West State Park	"	2,509
Hug Point State Park	Clatsop County	
Ecola State Park	"	1,172
Fort Stevens State Park	"	3,670
Washington Coast Area		
Fort Columbia State Park	Pacific County	
Fort Canby State Park	"	1,666
Bush Pacific Pioneer State Park	"	
Leadbetter Point State Park	"	
Twin Harbors State Park	Grays Harbor County	89
Ocean City State Park	"	140
Westhaven State Park	"	
Gungeness Marine State Park	Clallam County	36
Graveyard Spit State Park	"	
Sequim Bay State Park	"	89
Olympic National Park	Jefferson-Clallam County	289,600
Olympic National Forest	"	650,855
Fort Worden State Park	Jefferson County	339
Old Fort Townsend State Park	"	337
Fort Flagler State Park	"	804
Dosewallips State Park	"	424
Plesant Harbor State Marine Park	"	
Scenic Beach State Park	Kitsap County	71
Illahee State Park	"	75
Fay Bainbridge State Park	"	17
Kitsap Memorial State Park	"	65
Blake Island State Park	"	
Potlatch State Park	Mason County	57
Twanoh State Park	"	174
Belfair State Park	"	81
Squaxin State Marine Park	"	
Jarrell Cove State Park	"	51
South Whidbey State Park	Island County	85
Fort Casey State Park	"	137
Camano Island State Park	"	134
Deception Pass State Park	"	2,292
Fort Ebey State Park	"	

TABLE 71 (cont')

Washington Coast Area (cont')

Turn Island State Marine Park	San Juan County	
Prevost Harbor State Park	"	
James Island State Marine Park	"	
Sucia Island State Marine Park	"	
Matia Island State Marine Park	"	
Clark Island State Marine Park	"	
Moran State Park	"	4,934
Jones Island State Marine Park	"	
Posey Island State Marine Park	"	
Reid Harbor State Marine Park	"	
Larrabee State Park	Whatcom County	1,965
Birch Bay State Park	"	172
Bay View State Park	Skagit County	24
Edmonds State Park	Snohomish County	
Mukilteo State Park	"	14
Saltwater State Park	King County	88
Penrose Point State Park	Pierce County	145
Kopachuck State Park	"	104
Dash Point State Park	"	290

5 million days over 1969. The following table indicates the number of visitors per year to the major beaches in southern California, as an example of the high recreation use and demand in the Pacific coast region.

Table 72 Number of Visitors Per Year to the Major Beaches Administered by the California State Department of Parks and Recreation in the Southern California Coastal Region.

Beach	Number of Visitors
Leo Carrillo State Beach	328,517
Bolsa Chica State Beach	1,748,021
Huntington Beach State Beach	1,567,413
Doheny State Beach	536,435
San Clemente State Beach	329,625
San Onofre State Beach	212,650
Carlsbad State Beach	310,303
South Carlsbad State Beach	311,804
Leucadia State Beach	150,111
Moonlight State Beach	234,247
San Elijo State Beach	363,972
Cardiff State Beach	97,215
Torrey Pines State Reserve	417,861
Silver Strand State Beach	275,538

Source: California State Department of Parks and Recreation, Statistical Report 1972-1973.

Currently, about 25 percent of California's shoreline is used for public recreation. However, according to Article 15, Section 2 of the State Constitution, Californians have the right of access to the remaining privately-owned and used shore area, but this right has never been defined or guaranteed legislatively.

Federal recreation areas in the coastal California area include the Point Reyes National Seashore, Cabrillo National Monument, Channel Islands National Monument, Muir Woods National Monument, Redwood National Park, and the Golden Gate National Recreation Area currently being developed in the San Francisco Bay area, all administered by the National Park Service, as well as sections of the Los Padres National Forest, administered by the U.S. Forest Service. In addition, the National Park Service, under the authority of the Historic Sites Act (P.L. 74-292, August 27, 1935), gives recognition and consultative assistance to conservation efforts in natural areas by dedicating them as Registered Natural Landmarks. Various Federal and State wildlife-conservation management areas, discussed later in this section, also provide unique recreational opportunities within the California coastal area.

Oregon's scenic shoreline and beaches have long attracted both the people living on the coastal strip and those living in the populous Willamatte Valley, as well as tourists from throughout the country. The heavy tourist influx has created some strip-type recreational development along portions of U.S. Highway 101. However, intense development, similar to that found in southern California, has not occurred in Oregon. Over 40 percent of Oregon's shoreline is used for public recreation. Another 20 percent of the shore area has not been developed in any true sense, and much of the shoreline categorized as having private recreational uses (16 percent) has relatively little formal development. Where beaches exist and are accessible, the public has made use of the shoreline for recreation. This long historic usage is reflected in the "Beach Bill" legislation cited earlier. Along the Oregon Coast, there are approximately 60 parks and recreational areas developed by Federal and State agencies (indicated on Fig.78), individual counties, and private power and timber companies. Data gathered for 1968, including attendance at State Parks, forest camps, game units and marinas, indicate visitors totalling 14,871,000. A breakdown of these figures appears in the following table.

Table 73 Oregon Coastal Recreation Visitors, 1968

Coastal Section	Visitors
North Coast	2,060,000
Tillamook Bay	582,000
Yaquina Bay	1,325,000
20 Miracle Miles	1,875,000
Alsea Bay	1,561,000
Suislaw	1,598,000
Winchester Bay	1,236,000
Coos Bay	3,041,000
South Coast	1,593,000

Source: Oregon State Highway Division, State Parks and Recreation Branch.

The scenic Washington shoreline is one of the last untrammeled coastal areas in the Nation. No major highways closely parallel the coast, and access to the shore is by "gap" roads which head out to the beach. Off-road vehicles (ORV's) make considerable use of the broad sandy beaches which occur along the shore. Slightly over 6 percent of the State's total shoreline is used for public recreation, in the form of Federal and State parks, historic sites and pleasure-boat moorage facilities. Indian Reservation lands formerly open to public recreation are presently closed. Fishing picnicking, camping, hiking, beachcombing, clamming and crabbing are the recreational pursuits most often engaged in. Underwater recreation facilities for scuba divers are also located in various sites.

Recreational crabbing is practiced along the ocean coast, as is digging for hardshell and razor clams. Steelhead salmon runs also occur in many streams flowing into the ocean, similar to the rivers of Oregon. No rivers have been designated under the Wild and Scenic Rivers Act, nor have any been identified for study.

Nearly 2 million visitors were recorded in FY 1973 at just the five Washington State Parks listed below in Table 74. Day use of ocean beaches for FY 1973 was 940,000 for North Beach; 35,000 for South Beach; and 1,782,000 for Long Beach, as representative samples of recreational demand (Washington State Parks and Recreation Commission, 1973).

TABLE 74

NUMBER OF VISITORS TO WASHINGTON STATE SHORELINE PARKS, FY 1973

State Park	Visitors
Ocean City	360,000
Fort Canby	595,000
Westhaven	236,000
Fort Casey	455,000
Twin Harbors	280,000

Source: Washington State Parks and Recreation Commission, 1973.

(6) Conservation Areas, Pacific Coast Region

It is estimated that between 10 and 15 percent of the total 4,670-mile shoreline length of the Pacific coast region is composed of marsh/wetland areas. These areas are vitally important as resources that provide nutrient recycling, wildlife habitat, reproduction grounds, flood plain protection and erosion control, as well as opportunities for recreation activities involving wildlife and bird observation and photography, nature walks and aesthetic apprciation.

The wetland areas throughout this region are an integral part of the Pacific Flyway. Various Federal wildlife refuges are located in the region; the distribution is shown on the accompanying map. Table 75, following the map, indicates the Federal wildlife areas and their size, as well as some of the State wildlife management and conservation areas (where information was available) that have been established.

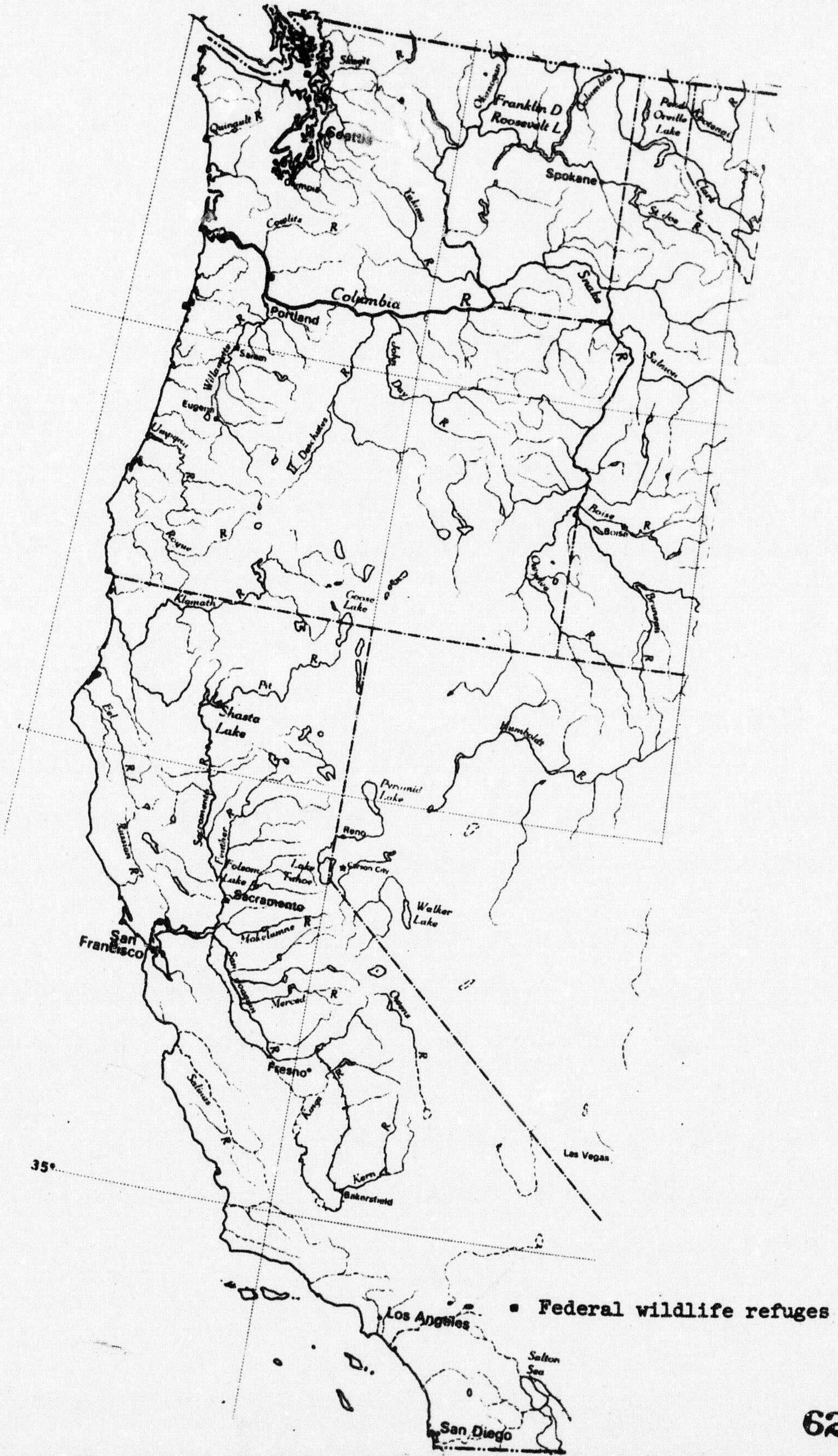

Skagit R
Quinault R
Seattle
Olympia
Okanogan
Franklin D Roosevelt L
Columbia
Pend Oreille Lake
Pend Oreille
Spokane
Clark
St Joe R
Yakima
Cowlitz R
R
Snake
Columbia R
Portland
Salem
Willamette
John Day
Deschutes R
Salmon
R
Eugene
Umpqua
R
Rogue R
Boise
Boise R
Owyhee
Bruneau
R
Klamath
R
Goose Lake
Pit R
Eel R
Shasta Lake
Humboldt R
Pyramid Lake
Reno
Sacramento R
Feather
Russian R
Folsom Lake
Lake Tahoe
Carson City
Walker Lake
Sacramento
San Francisco
Mokelumne R
San Joaquin
Merced R
Owens R
Fresno
Kings R
Salinas R
Kern
Bakersfield
Las Vegas
35°
Los Angeles
Salton Sea
San Diego
• Federal wildlife refuges

Figure 79 Federal Wildlife Refuges in the Pacific Region

TABLE 75

EXISTING FEDERAL AND STATE CONSERVATION-WILDLIFE MANAGEMENT AREAS

Area	Acreage
Name	
Southern California-Santa Barbara Coast Area	
Seal Beach National Wildlife Refuge	
Huntington State Beach Natural Preserve (Least Tern Sanc.)	
San Diego-LaJolla State Ecological Reserve	
Buena Vista Lagoon State Ecological Reserve	71
San Diego State Marine Life Refuge	
Scripps Shoreline Underwater Reserve	254
Doheny Beach State Marine Life Refuge	
Dana Point State Marine Life Refuge	
Niguel State Marine Life Refuge	
South Laguna Beach State Marine Life Refuge	
Laguna Beach State Marine Life Refuge	
Irvine Coast State Marine Life Refuge	
Newport Beach State Marine Life Refuge	
Farnsworth Bank State Ecological Reserve	
Santa Cruz Island Land and Water Reserve	56,000
Point Fermin State Marine Life Refuge	
Bolsa Chica State Ecological Reserve	563
Central California Coast Area	
Ventana National Forest Primitive Area	
Northern California Coast Area	
Farallon National Wildlife Refuge	211
San Pablo Bay National Wildlife Refuge	185
Humboldt Bay National Wildlife Refuge	76
Tomales Bay State Wildlife Preserve	
Oregon Coast Area	
Oregon Islands National Wildlife Refuge	367
Three Arch Rocks Nationals Wildlife Refuge	17
Cape Meares National Wildlife Refuge	139
Lewis and Clark National Wildlife Refuge	5,403
Columbia White-tail Deer Big Game Refuge	4,409*

* Located partially in Oregon and Washington.

TABLE 75 (cont')

Washington Coast Area

Ridgefield National Wildlife Refuge	3,017
Willapa National Wildlife Refuge	6,541
Copalis National Wildlife Refuge	5
Quillayute Needles National Wildlife Refuge	99
Flattery Rocks National Wildlife Refuge	125
Dungeness National Wildlife Refuge	756
Nisqually National Wildlife Refuge	1,295
San Juan National Wildlife Refuge	53
Jones Island National Wildlife Refuge	188
Matia Island National Wildlife Refuge	155
Smith Island National Wildlife Refuge	65
Columbia White-tail Deer Big Game Refuge	4,409*

* Located partially in Oregon and Washington.

Recognizing the importance of the coastal zone, the Pacific region States have established various coastal zone management laws for the purposes of protecting and regulating the uses that can be made of this resource. Examples of some of the State statutes are listed below.

TABLE 76

STATE COASTAL ZONE MANAGEMENT-RELATED STATUTES

California	Coastal Zone Conservation Act of 1972; Environmental Quality Act of 1970
Oregon	Beach Access Act of 1969; Oregon Land Use Act of 1973 (S 100)
Washington	Shoreline Management Act of 1971

In response to the Federal Coastal Zone Management Act of 1972, the States are developing and implementing Statewide coastal management programs, and are in the process of establishing guidelines and regulations that will provide coordinated planning and development of coastal zone resources as well as identify and delineate areas of particular critical environmental concern.

(7) Transportation

Major Ports and Shipping

Shipping plays a major role in the economy of the Pacific coast region because of the size and location of natural harbors which are sheltered from the sea. The ports extend the entire length of the coast from San Diego to the Puget Sound area in Washington. The importance is noted by the growth of activities for both imports and exports for Pacific ports since 1950. The U.S. Bureau of the Census indicates the growth in activities in thousands of short tons):

Year	Imports	Exports
1950	4,095	7,270
1955	9,038	13,394
1960	23,281	19,351
1965	29,995	26,445
1967	26,223	36,486
1968	28,292	39,146
1969	31,957	41,018
1970	30,846	47,518
1971	39,255	37,664

The data depicts the growth over the 21-year period and indicates a sevenfold increase in just the commercial activities.

There are only three designated ship traffic lanes along the Pacific coast. The first runs northerly from Los Angeles through the Santa Barbara Channel, the second is the approach network outside the San Francisco Bay, and the third is from Los Angeles-Long Beach Harbors to San Clemente Island.

Table 77 shows the major ports of the Pacific conterminous U.S., and their handled volume of traffic in 1972.

TABLE 77

SHIPPING COMMERCE - MAJOR PACIFIC U.S. PORTS

Port	Total Commerce(tons)
San Diego Harbor	1,666,283
Long Beach	20,795,050
Los Angeles Harbor	23,836,690
El Segundo	5,157,833
Estero Bay	4,026,962
San Luis Obispo Harbor	1,396,343
Ventura Harbor	2,353,120
San Francisco Bay	44,560,899
Coos Bay Harbor, Oregon	6,543,775
Columbia River vicinity	20,282,863
Grays Harbor, Washington	3,785,907
Seattle	14,662,811
Port Angeles	2,849,121
Tacoma	8,477,318

Source: U.S. Army Corps of Engineers, 1972.

Major Interstate Highways

Interstate 5 runs the entire length of the Pacific coast region, and connects the major metropolitan areas from San Diego northward to the Canadian border. Interstate routes linking with I-5 extend eastward from the Pacific region, and include I-90 east from Seattle; I-80N east from Portland; I-80 east from the San Francisco Bay area; I-15 and I-10 east from Los Angeles; and I-8 east from San Diego. Many stretches of Interstate 5 are inland, lying between the Coast Range and the Sierra Nevada and Cascade Range. Highway 101, or the Coastal Highway, serves the coastal zone area proper.

Railroad System

Extensive railroad complexes, particularly freight systems, connect the entire Pacific region's major urban areas. In many cases, the smaller coastal towns and cities are connected to the major lines via feeder lines. Principal railroad systems connect the West Coast with the rest of the Nation, primarily from the Northern Great Plains (Burlington-Northern), the Rocky Mountain route and the Southern route (Union Pacific, Southern Pacific and Western Pacific).

Aviation Routes

Major commercial airports connecting the large urban centers of the Pacific coast region are located at Seattle-Tacoma, Portland, San Francisco, Los Angeles-Long Beach and San Diego. Smaller regional airlines connect many of the coastal cities and towns with the larger urban areas. The West Coast feeder airlines are particularly heavily used between San Diego, Los Angeles and San Francisco.

Pipelines

Because of the petroleum resources (onshore and offshore) contained and/or processed within California, a pipeline infrastructure has developed that includes gas as well as crude oil and products pipelines. These lines, concentrated largely in the Los Angeles to Central Valley of California area, carry oil and gas and petroleum products to processing and consuming centers throughout California and other western U.S. areas.

(8) Historical and Projected Growth in the Pacific Coast Region

During the past decade Oregon has not been very successful in its hope for limited population growth; it experienced an increase of over 18 percent compared to the national average of just over 13 percent. For the period 1970-80 the State is expected to experience a 15 percent increase, with the greatest increase in the metropolitan areas of Portland, Salem and Eugene. The coastal counties showed little change during the past decade, except in Lane County. However, the 1970-80 period is expected to change with the rate of growth going up sharply.

Oregon is moving from a traditional resource-oriented economy--one highly dependent on timber, agriculture and fishing to a more diversified base. The 1960's brought a doubling of employment in metals and machinery and a two-thirds growth in finance, industry, realty and services. By 1970, jobs in the lumber industry were down to 67,100 some 26,000 less than 1950, while jobs in manufacturing were steadily increasing.

TABLE 78

MANUFACTURING ECONOMY IN THE PACIFIC COAST REGION, 1971

	California	Oregon	Washington
Total Employees (1,000's)	1,447.3	169.4	220.7
Production Workers (1,000's)	739.2	131.9	148.2
Value Added by Manufacturing (Million $)	27,568.2	2,806.6	4,117.0

Oregon's gross State product is just below $10 billion a year, compared to California's $126 billion. Although all manufacturing as a whole is increasing, in terms of single industries, timber still leads (value added $1.8 billion in 1970), followed by agriculture and tourism. Total personal income between 1964 and 1971 increased from $4,851 to $8,446 billion, a 73 percent increase. Per capita income for the three States is shown in the table below, followed by a table showing the agricultural economies of this area.

TABLE 79

PER CAPITA INCOME IN THE PACIFIC COAST REGION

	1969	1972	% Change
California	4,218	4,988	+ 18.3
Oregon	3,498	4,287	+ 22.6
Washington	3,938	4,472	+ 13.6

Washington has shifted rapidly from an old wheat/timber extractive industry base to a manufacturing base. Prior to World War II, 75 percent of the employment was in agriculture and forest products; currently it is one-third, while aerospace and other manufacturing accounts for two-thirds. Value added by manufacturing is over $4 billion as shown in Table 78 . In peak years, aerospace has accounted for $1 billion. Other industries include food and food products, metals, chemical, machinery and shipbuilding. Inexpensive hydroelectric power from dams along the Columbia River are responsible for a $400 million-per year alumium reduction industry.

Per capita income increased 13.6 percent in Washington, as indicated on Table 79. In 1969 it was above the national average, however, by 1972 it fell slightly below, in due partly to unemployment in the huge aerospace industry. The State's personal income has increased at the same rate as the nation--almost 50 percent between 1964 and 1972--and reached a level of $12.8 billion. This represented 1.6 percent of the total U.S. personal income.

TABLE 80

AGRICULTURAL ECONOMY IN THE PACIFIC COAST REGION, 1972

	California	Oregon	Washington
Total Cash Farm Receipts (Million$)	5,596.5	668.8	1,080.9
Receipts from Cash Farm Crops (Million$)	3,268.3	355.4	692.2
Receipts from Live-stock & Products (Million$)	2,205.8	288.8	332.3

Non-agricultural employment accounts for about 97 percent of the 8 million civilian labor force in California. In 1970, the principal business sector employers were trade (19.7 percent of employees), followed by manufacturing (18.8%), government workers (17.5%) and the services sector (17.1%). The greatest stimulus to California's economic and population growth came between 1950 and 1960 as a result of defense spending. Trade provides the second largest number of jobs among the five southern California counties, followed by the services sector. Government employment provides the fourth highest number of jobs in this area.

For California as a whole, total personal income totalled $112 billion in 1973, up almost 10 percent from 1972, and accounted for 11 percent of the total U.S. personal income. Los Angeles County with a personal income of $41,845 million, combined with San Francisco and Oakland area's income of $20,742 million, account for more than half the State total. Per capita income increased 18 percent from 1969 to 1972 as shown in Table 79.

The agricultural economy is highly significant in California, and is the largest in the U.S. It is considered one of the most diversified in the world. Total cash farm receipts reached nearly $5.6 billion in 1972, as shown on Table 80 and was a billion dollars greater than Iowa, the second ranked State.

(9) Commercial Fisheries in the Pacific Coast Region

Because of the method of handling catch data according to State or region it is most convenient to divide the commercial fisheries discussion of the Pacific coast into California and the Pacific northwest (Washington and Oregon). References for the California portion of this report came from Leet and Cramer (1971) and Frey (1971) while that of the Pacific Northwest came from Glude (1971).

The following table indicates the volume and value of commercial landings in the Pacific coast region.

TABLE 81

PACIFIC COAST REGION COMMERCIAL LANDINGS, By State, 1972-1973

	1972		1973	
	Thousand Pounds	Thousand Dollars	Thousand Pounds	Thousand Dollars
California	639,764	91,898	669,159	102,642
Oregon	92,923	24,024	87,838	28,410
Washington	120,458	38,496	117,269	47,219
TOTAL-PACIFIC COAST REGION	853,145	154,418	874,266	178,271

SOURCE: U.S. Dept. of Commerce, National Marine Fisheries Service, 1974.

The largest fishery of California-based fishermen is tuna. The port of San Pedro has been the Nation's leading port in terms of the value of landings (and until recently, total poundage) for over 20 years. These large landings are misleading, however, because over 80% of the tuna caught are landed outside California waters off Mexico and Latin America. Bluefin tuna and albacore are the main tuna caught in California waters during their summer migrations into the area. In addition to the summer tuna migrants, pelagic fisheries include jack and Pacific mackerels, anchovy, sardine and squid. In the northern part of California, Pacific herring are more important. Until the late 1940's the Pacific sardine was an extremely important fishery in the California Current. After this time its population, and therefore its landings, decreased drastically and the sardine catch was replaced by the anchovy catch. In addition to over-fishing, surface current variation and water temperature change may have contributed to the sardine population decrease. The Pacific mackerel is another species which has apparently been depleted by over-fishing.

The bottomfish fishery is less well developed from Santa Monica Bay and further south than in the central part of the State and further north. Rockfish are the principal fish taken in these southern regions, while flatfishes, rockfishes, sablefish, lingcod, and hake are taken further north.

The salmon fishery is also best developed in the central and northern part of the State. The chinook or king salmon accounts for the vast majority of the catch.

The principal shellfisheries are crabs, shrimp, spiny lobsters, abalone, and oysters. The market for Dungeness crab fishery is centered in the San Francisco and Eureka area while the relatively new rock crab fishery is centered in the southern part of the State. Bay shrimp and the recent ocean shrimp fishery are best developed in central California. Abalone and spiny-lobster fisheries are best developed in the southern and central part of the State.

In the Pacific Northwest (Oregon and Washington), the relatively narrow continental shelf and large inland bays, especially Puget Sound and much of the Columbia River, harbor large fisheries for salmon and bay fisheries. The value of Pacific Northwest fishing products as shown in Table 81 is about 10% of the total value of U.S. fishing products.

Major fishery species include salmon (chinook or king, coho or silver and red or sockeye), many of which are caught near the mouth of the Columbia River by gill netting and purse seining. Bottom fishes, such as flatfishes, rockfishes (including Pacific ocean perch), Pacific cod and Pacific hake are taken principally by otter trawl. Halibut are caught with longlines.

Pelagic fisheries of the Pacific northwest include albacore tuna (during their summer migration into the area), Pacific herring and northern anchovy. Only albacore and herring have been landed in large quantities.

Shellfish include the native (Olympia) and larger Pacific oysters, essentially raised by mariculture, and several species of clams (more important as a recreation fishery than a commercial fishery). The most important clams of the area are the razor clam, butter clam, native littleneck clam, and manila clam introduced from Japan. Crustaceans taken commerccially in the Pacific northwest are mainly Dungeness (market) crab and pink Pandalid shrimp.

(10) Oil and Gas Resources, Pacific Coast Region

The following estimates of oil and gas resources in coastal State waters are provided by the U.S. Geological Survey. USGS emphasizes that the estimates are speculative; only the maximum credible expectations are shown.

TABLE 82

CURRENT (1972) OIL AND GAS PRODUCTION FROM
COASTAL STATE WATERS

(Oil in billion barrels; includes natural gas liquids)
(Gas in trillion cubic feet)

Area	Oil	Gas
Southern California	0.1	0
Santa Barbara		
Northern California	0	0
Washington-Oregon	0	0

TABLE 83

ESTIMATES OF UNDISCOVERED RECOVERABLE RESOURCES
IN COASTAL STATE WATERS*

(Oil in billion barrels; includes natural gas liquids)
(Gas in trillion cubic feet)

Area	Oil	Gas
Southern California	0-1	0-3
Santa Barbara	0-1	0-3
Northern California	0-1	0-3
Washington-Oregon	0-1	0-3

---

* On March 26, 1974, the U.S. Geological Survey released estimates of the undiscovered recoverable oil and gas resources for broad areas of the OCS. Those estimates were based on statistical parameters of oil occurrences that apply only to broad geographic areas. It is entirely inappropriate to apply the same parameters to small, specific areas. The resource figures in the above table represent a general estimate, based on the above referenced information, of minimum and maximum volumes of oil and gas that might be recovered from various OCS areas. It is statistically unsound to add the maxima and minima for an expectable range of resources for any larger area. New estimates have recently been prepared by the USGS for the undiscovered recoverable resources in OCS areas, and are discussed in the Description of the Proposed Action.

TABLE 84

MEASURED AND INFERRED RESERVES IN COASTAL STATE WATERS
(December 31, 1972 Estimates)

(Oil in billion barrels; includes natural gas liquids)
(Gas in trillion cubic feet)

Area	Measured Reserves		Inferred Reserves	
	Oil	Gas	Oil	Gas
Southern California Santa Barbara	0.7	0.7	0-0.5	0-0.5
Northern California	0	0	0	0
Washington-Oregon	0	0	0	0

The 1973 production from Pacific coast upland areas (California) was 335,741,000 barrels of crude oil, 12,461,000 barrels of natural gas liquids and 478,356 million cubic feet of natural gas. Production first began in 1861, and was highest in 1968, declining since then.

d. Existing Environmental Quality Problems in Coastal Zone

(1) Water Quality

Southern California

The following descriptions have been taken from the California Region Framework Study Committee (1971). Water quality may presently be of higher quality than stated due to the efforts of the EPA's administration of the National Pollutant Discharge Elimination System.

In the San Diego Bay area, large quantities of wastes in the form of raw waste water, garbage, trash, grease and oil are one of the causes of pollution of the Bay.

Because of water deficiency, extensive ground-water recharge projects using treated waste water are operated. Most percolation beds are in river channels or on land near streambeds. During the rainfall season, treated waste water overflows from percolation beds and/or from drains in irrigated fields. Nutrients from waste water combine with the urban runoff to enrich many coastal lagoons. The enrichment promotes excessive algal blooms and aquatic growths, oxygen depressions and odor problems.

The submarine outfalls of the South Coastal Subregion are among the largest in the world. In addition, there are numerous small discharges through short outfalls serving smaller coastal cities. Where disinfection practice is marginal, smaller outfalls are sources of coliform bacteria to the recreational beaches and shellfish areas. Floatable materials from marine outfalls, channel debris and waste from vessels have been a major concern in waters near Los Angeles and Long Beach and many other marine shore communities.

The estuarine area of the San Gabriel River receives condenser cooling water from two large (1,000 megawatts) thermal-electric power plants, with a resulting 15° to 19°F. increase in estuarine water temperatures. As a result of the increased temperature and the natural nutrients in these waters, a tropical aquatic ecology has developed in the estuarine reach. During the heavy runoff season, the high stream discharges flush the estuary, transporting large quantities of aquatic growths to San Pedro Bay. The decomposition of these aquatic mats creates potential pollution and odor problems which can adversely affect the beneficial uses of San Pedro Bay.

The Los Angeles-Long Beach Harbor complex receives large volumes of municipal and industrial waste which depress dissolved oxygen levels and cause odor problems. Waste brines from refineries and oil fields are discharged into the inner harbor.

In the area along the coastal waters of Ventura County, brine and waste waters from nearshore and offshore oil well development are sources of oil contamination in beach areas. Several large natural sub-marine oil seeps in the area contribute to the problem of the extensively used recreational beaches. On the Channel Islands, also offshore of Ventura County, a zero hatch of Brown Pelican eggs has been reported as being related to pesticides, e.g., only one pelican was produced out of an estimated 1,000-plus eggs layed during the 1970 nesting season.

Central California

Water quality problems presently exist within the Central Coastal Subregion as illustrated by such recent events as bacterial contamination of recreational coastal areas at Monterey and Carmel, the massive offshore oil spill incident near Santa Barbara (January, 1969), the occurrence of algal growth in parts of the San Lorenzo River, localized inland pollutional problems directly attributable to irrigation drainage and waste discharges and deteriorating groundwater quality.

Bacterial contamination is evident in certain portions of Monterey and Carmel Bay where recreation demand is very high. Coliform bacteria, an indication of the level of pollution, has exceeded the standards for water contact sports from Seaside to Monterey and a portion of Pacific Grove beach area. Problems of this nature are closely allied to the lack of adequate treatment of municipal waste at various locations and also other industrial discharges.

Natural seeps from the ocean floor are potential sources of oil pollution in beach area. Union Oil Company operations on the Outer Continental Shelf contributed to the extensive oil pollution incident near Santa Barbara which resulted in oil-coated beaches, killed thousands of waterfowl, endangered nearshore ecology, and coated boats and structures, all of which resulted in tremendous economic loss to this recreational area. The chance of recurrence of oil spillage is present although tighter safety precautions have reduced the probability of large spills.

Due to the intermittent nature of most inland streams in the subregion, water quality degradation results. This occurs through drainage from irrigated lands reaching relatively dry streambeds, thus forming the major portion of streamflow. Other incidents of water pollution result from bypassing or overflow from land disposal areas for municipal waste water to drainage-ways or streambeds. When streamflow reach levels of flooding conditions, the accumulated waste constituents from overflow, refuse or solid waste in the streambed is washed downstream to estuaries and bays.

San Francisco Bay Area

The high sediment load and turbidity in the Russian River has been a source of complaints by fishery interests. Water is imported from the adjoining Eel River Basin during the low flow season when eutrophication of impounded and flowing waters is evident. The large nutrient loads from treated waste water, septic tanks, and natural runoff have been a cause of prolific algal blooms along this recreational waterway. Bacterial contamination has been a problem in the Russian River Basin, although now minimized by recently constructed facilities. At the mouth of the river near Jenner, seawater intrusion into groundwater has been a local problem.

Tomales Bay, Bolinas Lagoon, and Bodega Bay experience violation of minimum bacteriological standards due to the discharge of municipal waste and dairy waste.

Depressed levels of dissolved oxygen in the extreme portions of South San Francisco Bay occur during the late summer and early fall months due to municipal waste discharge. Dissolved oxygen deficiencies also occur in the Petaluma River and are attributed to dairy waste discharges and the City of Petaluma's waste discharge. Widely fluctuating levels of dissolved oxygen observed in areas of limited circulation in San Francisco Bay and in adjacent coastal areas have been attributed to algal growths. These growths have caused complete lack of dissolved oxygen in the extreme reaches of some tidal sloughs, creeks and rivers, and have caused pH values up to 9.0. Green seaweed along mudflats are particularly apparent in the Bay system during the summer and fall when decomposing mats emanate hydrogen sulphide. Recent years have brought red water discoloration caused by a planktonic marine organism, a phenomenon probably aggravated by high nutrient concentrations.

Fish kills have occurred in the Bay system as the result of accidental spills of toxic materials and inadequately treated waste water and industrial waste discharges. Major kills of striped bass and sharks have occurred in Suisun Bay, Aquatic Park, and near Alameda with the cause generally unknown.

Pesticides in the Bay system originate from municipal storm sewer and sanitary sewerage systems, urban runoff and drainage, and from the vast agricultural lands in the Central Valley. The presence of these pesticides is as yet a threat of unknown magnitude to the fisheries and wildlife resources. This threat must be more fully evaluated and all agricultural drainage facilities serving the Central Valley should be carefully monitored and treatment or control measures instituted where warranted.

Recent studies made as part of the San Francisco Bay-Delta Water Quality Control Program found that, of the seven sub-areas of the Bay system, only the North San Francisco Bay appeared to conform with the bacteriological objective adopted by the Regional Board for the protection of the public health. Substantial improvement in the bacteriological quality of the waters of Central San Francisco Bay has been reported by the State Department of Public Health after the initiation of disinfection of waste discharges by East Bay Municipal Utility District and the City of San Francisco at its Southeast Plant.

At present, all portions of the Bay system are quarantined by the State Department of Public Health from harvesting shellfish for human consumption because of contamination by waste discharges. The delineation of areas to be protected for shellfishing are available from the State Department of Fish and Game.

Sediment and turbidities are important factors affecting bottom organisms and the aesthetic values of the waters. The past oyster fishery has been lost due in part to sedimentation. Deposited sediments are resuspended by maintenance dredging of navigation channels and boat harbors, deepening of navigation channels, overflows from hydraulic landfills, wave action from vessel wakes, and wind and tide induced currents.

Water quality problems resulting from the filling of tidelands are numerous, complex, and not fully understood. They are the subject of study by various agencies including the San Francisco Bay Conservation and Development Commission (BCDC) and the State Water Resources Control Board. Under recently enacted legislation, any person or governmental agency planning to fill the Bay, or to extract submerged materials from the Bay is required to secure a permit from the BCDC.

Limited data are available on the effects on water quality by discharges from combined waste water systems, bypasses of waste water from sanitary waste water systems overloaded because of storm water, and the discharge of storm water runoff. Nevertheless, obvious problems are the direct result of such discharges.

The discharge of oily wastes and waste water from boats and vessels is a water quality factor associated with navigation and recreational boating, causing conditions contrary to water quality objectives. Presently there are local efforts to connect houseboats to sewer systems. Recent State legislation (1970) and vigorous enforcement should adequately control the houseboat problem.

The San Francisco Bay area has experienced oil pollution problems localized at refinery docks, ports, marinas, and near storm sewer outlets attributable to accidental spills, deliberate discharges, pipeline leaks and pumping of oily bilge or ballast water. During the period of January, 1968, to June, 1969, 235 oil spills were reported in San Francisco Bay from all sources.

Waters near the City of San Francisco discharge points and beach areas both in the ocean and inside the Bay usually do not meet bacterial standards for swimming quality. San Francisco has a combined sewer system which, during wet weather, discharges untreated waste water to the Bay and the Ocean causing contamination.

The deep coastal water disposal of cannery wastes, industrial wastes from petro-chemical processes, waste from steel operations, explosive and toxic wastes are potential pollution problems. Dredging spoil from existing and new ship channels and bay mud from other construction activities is usually disposed of at designated areas within the Bay system; however, some dredged material is spoiled in the ocean outside the Golden Gate.

Northern California

In the Crescent City and Humboldt Bay area, unsewered subdivisions presently served by septic tanks create pollution problems during the wet season. There is a need to connect these subdivisions to the local municipal system where proper treatment can be provided. Disinfection practices in existing waste water treatment plants including oxidation ponds which discharge to Humboldt Bay should be improved to insure compliance with bacteriological standards in receiving waters to protect the valuable shellfish resource. Harbor pollution from shore installations, vessels, and small fishing and pleasure craft at Crescent City and Humboldt Bay cannot be ignored since bacteriological contamination is likely from these sources. Oil spills have occurred which contaminated shellfish areas, killed water fowl, and affected the estuarine plant foods and birds.

At Ft. Bragg and Noyo Harbor, organic pollution problems are critical. Fort Bragg does not have a community sewerage system and discharges raw waste water directly to the ocean. Fort Bragg is the last town of its size (5,000 pop.) in the California Region to discharge untreated waste water to surface waters. Noyo Harbor does not have a community sewer system, and individual septic tanks and cesspool systems are common in the harbor. Fish processing plants, restaurants, fishing boats and other commercial enterprises have added to the pollution problems of the harbor. Fish kills have occurred in the Noyo River as a result of pollution.

Erosion and siltation are major problems of all drainage basins in the North Coastal Subregion. Land disturbances related to logging, road construction, mining and forest fires have contributed to turbidity and siltation of North Coastal streams. Siltation of stream bottoms smothers sensitive benthic fauna essential to fish production. Clogging of spawning gravels further reduces recreational fishery production so important to this area. Proper land management designed to control excessive sediment production in the subregion is essential to maintenance of the present North Coastal aquatic environment.

Mine drainage within the North Coastal subregion has on occasions caused severe losses of fish due to high dissolved solids loads or heavy metals, such as copper, being discharged from active and abandoned mining operations.

Pesticide concentrations in the lower Lost River are presently high enough to cause concern about the effect on the aquatic environment and wildlife.

Oregon & Washington

The following information has been taken from the Columbia-North Pacific Region Comprehensive Framework Study (1971).

In general, the waters of the subregion are of excellent quality and are suitable for all uses. The most commonly encountered problems include high coliform bacterial counts, high temperatures, and high nutrient levels. A few instances of low dissolved oxygen are found, and high turbidities and sedimentation are encountered during some periods of the year. Water quality deterioration from toxic materials has not been documented, although phenolics associated with plywood production and sulfites associated with pulp and paper production are discharged to subregional waters.

The marine and estuarine waters of the subregion are of prime importance for recreation, as clam and oyster rearing areas, and for passage of anadromous fish. In several estuaries, discharges of untreated or inadequately treated domestic and industrial wastes and agricultural runoff have seriously degraded water quality. These estuaries include Coos Bay, Umpqua Bay, Yaquina Bay, Nehalem Bay, Tillamook Bay, and Grays Harbor.

Dissolved oxygen levels are generally satisfactory for fish passage in most marine waters; however, Coos Bay, Yaquina Bay, and Grays Harbor do exhibit oxygen depressions during certain periods of the year. In Coos Bay, oxygen levels of one to two mg/l have been reported during late summer and early fall. In Yaquina Bay and Coos Bay, depletion of oxygen levels during the summer months is caused by the very low inflow into the bays and large waste loading. This inflow is not large enough to allow flushing and, thus, a pool of water is trapped until high water flows force the low DO water out. A periodic phenomenon in Grays Harbor which results from particular conditions of wind and current, referred to as upwelling, replaces bay water with low DO water which is forced up from great depths offshore. The DO content of the deeper waters may be as low as one to two mg/l. When upwelling occurs during the season of high temperatures and low streamflow, it reduces the estuary's ability to provide the needed oxygen resource and thereby intensifies the oxygen deficit.

In several areas of the Oregon Coast, discharges of untreated or inadequately treated domestic and industrial wastes and agricultural runoff have reached the point of causing a threat to health. These areas include Nehalem Bay, Tillamook Bay, Yaquina Bay and Umpqua Bay. The most significant of these areas are Yaquina and Tillamook Bays, where recently the Public Health Service "conditionally approved" oyster growing areas with the stipulation that action be taken to reduce coliform levels in the bays.

Toxic sulfite waste liquor effluents from pulp and paper mills and phenolics associated with plywood production have deteriorated water quality in Coos Bay, Yaquina Bay and Grays Harbor. The discharges have resulted in unsightly and interfering floating materials as well as rendering some areas sterile for normal aquatic populations.

(2) Air Quality

In terms of air quality problems along the Pacific Coast Zone the only significant areas are located in Southern California, particularly in the Los Angeles Metropolitan Area. The other areas have minor problems which are not considered to be significant. The areas outside of Southern California do not have existing problems that would be aggrevated by the introduction of offshore oil and gas activities.

In the State of Washington the coastal zone is limited to a narrow stretch between the Pacific Ocean and the Olympic Mountains. It is located within the southwest region, a division of the state air pollution control function, and represents one broad air basin. The two main urban areas are centered around the Grays Harbor area and the Astoria, Oregon, area on the Columbia River. The Washington Department of Ecology reports that there are no air quality problems existing in the coastal zone because of the flushing action of the winds, the lack of major industry, and the small number of automobiles. There are minor local disturbances of air degradation resulting in particulate matter emissions from the lumbering industry, but a close monitoring system is maintained by the air control agency.

The air quality situation along the coastal zone in Oregon is very similar to that of Washington. The coastal zone is a narrow band located between the Pacific Ocean and the coastal range of mountains and is mostly forested with the exception of the small urban centers. The lack of air quality problems is evidenced by the fact that the Oregon Department of Environmental Quality only has intermittent monitoring along the coast.

The stations are located in the Coos Bay area and in Astoria along the Columbia River. In Coos Bay the monitoring program is directed towards particulate matters that originate with the lumbering industry. In Astoria sulfur dioxide emissions are monitored. Because of similar terrain and wind actions as that found in Washington, there are no air quality problems of any significance.

The major air pollution problem in California is photochemical air pollution which is caused by atmospheric reactions of hydrocarbons and oxides of nitrogen in the presence of sunlight. Although of less severity, carbon monoxide and suspended particulate matter do affect the ambient air quality. Problems caused by other pollutants such as lead, nitrogen dioxide and sulfur dioxide are not as severe but often do exceed the ambient air quality standards.

Low concentrations of all pollutants occur naturally although the levels may not be the same in all locations. Common background levels of various air pollutants are shown below and compared with air quality standards.

Pollutant	Background Level	Federal Air Quality Standards
Oxidant	0.04 ppm	0.08 ppm (1 hour)
Carbon Monoxide	1.0 ppm	9.0 ppm (8 hours)
Nitrogen Dioxide	.004 ppm	0.05 ppm (Annual)
Suspended Particulate Matter	20-40 ug/m3	75 ug/m3

Sulfur dioxide and hydrogen sulfide are emitted by localized underground sources and do not have widespread background levels. Natural background levels of particulate matter are created by salt spray and sand near the coast and by wind blown dust and pollens inland.

Large quantities of man-made pollutants are emitted into the atmosphere daily. California statewide emissions are as follows:

Nitrogen oxides	3,800 tons per day
Hydrocarbons	5,900 tons per day
Carbon monoxide	24,000 tons per day
Suspended particular matter	1,900 tons per day
Sulfur dioxide	990 tons per day

The South Coast Air Basin (Los Angeles Area) has forty-nine percent of the California population, six percent of the land area, and produces thirty-eight percent of the total tonnage of air pollutants.

Emissions from motor vehicles account for the greatest portion of hydrocarbon, oxides of nitrogen and carbon monoxide pollution. Industry and agriculture are responsible for the majority of the man-made particulate matter in the atmosphere.

The South Coast Air Basin in a large flat basin in which air movement is impeded by mountain ranges to the east and north. Prevailing winds from the Pacific Ocean carry the pollution towards the mountains. The condition is aggravated by an atmospheric temperature inversion which is often present. During the inversion, a layer of warm air overlies cooler air which acts as a lid by trapping pollutants in the lower air mass.

The concentration of all the pollutants commonly measured exceeded air quality standards in the Los Angeles area in 1973. As a result, the air quality problem is significant in the Los Angeles area.

The San Francisco Bay Area has been relatively free of smog, compared with Los Angeles, because the onshore air flow drawn inland in the sumer and fall by the thermal low in the Central Valley of California ventilates the area. However, concentration of oxidants carbon monoxide, nitrogen dioxide and particulate matter did exceed state standards in 1973. While the city of San Francisco has low oxidant readings, maximum one hour oxidant concentration approached or exceeded the health advisory alert level in Alameda, Contra Costa, San Mateo, Solano and Santa Clara Counties, with the most severe oxidant levels recorded in Mountain View and San Jose where they reached the .30 ppm range.

The potential for the production of photochemical air pollution in the San Diego area results from frequent low inversions and an abundance of sunlight. San Diego weather is characterized by few clouds, light winds, and moderate temperature with small diurnal variations in the coastal plain. Stagnant conditions occur frequently in the inland valleys.

In terms of air quality problems, the Pacific Coast areas of Southern California are most affected. With the absence of major urban developments along the coast of California and the physical features of the land, the chances for problems resulting from offshore oil and gas operations remain small. The areas of Oregon and Washington are similar to those found along the majority of the California coast and do not represent any problems.

(3) Dredging

Dredging is a process commonly used along the entire length of the Pacific Coast to keep harbors open and to increase the depth of navigable channels. Dredeging produces a large quantity of spoil which is potentially dangerous to the environment since its redeposition can adversely effect the biota. Silt and clay are the primary deleterious grain sizes.

Special areas are designated for the dumping of dredge spoil. Spoil with silt and clay components is best disposed of on land. However, this is not always possible. Hence, a number of offshore sites are designated as acceptable for dredge spoil disposal by the Environmental Protection Agency. There are twelve approved disposal sites in northern California, and five sites in southern California. Similar sites are present off Washington and Oregon.

4. Alaska Region (and Sub-area)

a. Geology

The geology of the nearshore and coastal zone has been described previously in the discussion of the offshore environment (section II.A.4.a.) since unlike biological and some other physical parameters, geologic structures are not commonly distinguished according to an arbitrary division based on water depth or proximity to the shoreline. Where specific geologic structures are unique to a nearshore area, they are noted as such.

b. Biological Environment and Communities of the Coastal Zone

Alaska's coastline is long, diverse and complex. The general coastline (including inlets, bays, etc.) is about 47,300 miles long. Much of the tidal shoreline is a labyrinth of fiords, islands, bays, and rocks. The Arctic shoreline is composed of a series of lagoons and barrier beaches.

The coast of Alaska covers a broad range in latitude and longitude, and includes ecosystems grading from temperate to extreme arctic. The Arctic coast system is unique to Alaska. Associated with the Arctic coast are biological communities found on and under the ice. These communities have been discussed previously in the Biological Environment (Section II.A.4.d.).

The biological environment of Alaska's coastlines is very poorly known. Fortunately, however, there is a considerable overlap of species and genera along the North Pacific coast from California to Alaska. Therefore, out-of-state references are useful to some extent, particularly in the Gulf of Alaska where faunal assemblages resemble those of the Pacific coast region discussed previously (Section II.B.3.b.). Many other aspects of the coastal region have been covered in The Biological Environment of Alaska (Section II.A.4.d.).

The most extensive research in the Alaska intertidal zone has been done for Prince William Sound, Amchitka, and Kodiak Island. These studies were conducted to examine the effects of the Alaskan earthquake in 1964 (Prince William Sound and Kodiak) and underground nuclear explosions (Amchitka). These studies were quantitative, but did provide additional taxonomic knowledge. In general, flora and fauna in the three areas were grouped into three major zones depending on the local tide range and wave heights. These studies have been briefly summarized by Feder and Mueller (1972) who also suggest areas of biological research which are in need of study (ecological relationships, dominant community members, etc.) in the Gulf of Alaska.

Despite the lack of detailed ecological studies of the Alaskan coastline, some impression of the diversity of shoreline communities can be obtained from an inventory of ecosystems as outlined by McRay, et al. (1969). Figure 80 illustrates six broad biological regions in coastal Alaska, each designated by a number. Ecosystems within each of the regions are listed in Table 85 with representative locations. Those areas in the Gulf of Alaska exhibit nearly twice as many ecosystems as the Arctic Ocean shoreline, although the latter area has no man-induced stresses listed (sewage wastes, paper mill wastes, etc.).

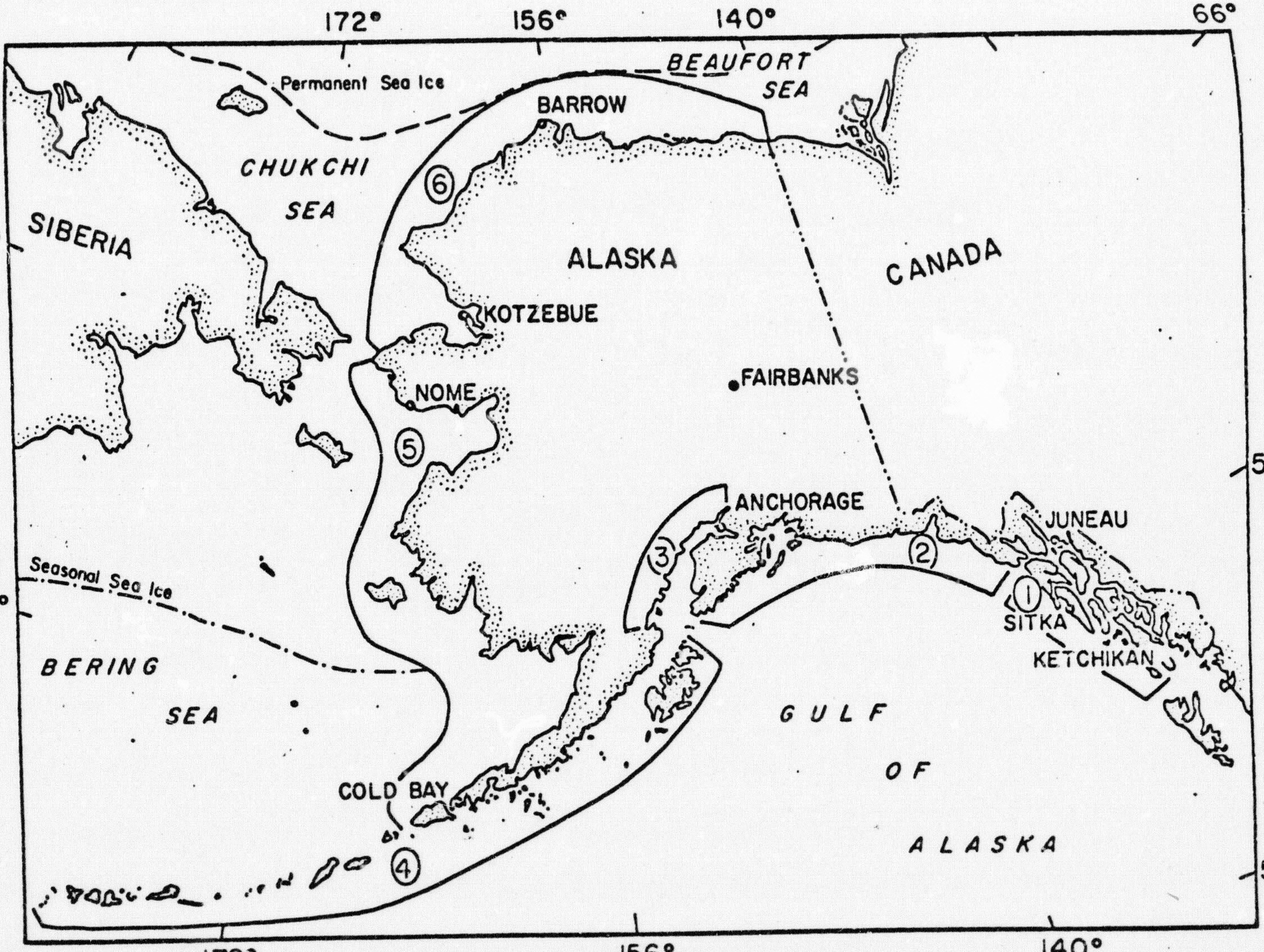

172°
156°
140°
66°
Permanent Sea Ice
BEAUFORT SEA
BARROW
CHUKCHI SEA
6
66°
SIBERIA
ALASKA
CANADA
KOTZEBUE
FAIRBANKS
NOME
5
58°
ANCHORAGE
JUNEAU
3
2
1
SITKA
KETCHIKAN
Seasonal Sea Ice
58°
BERING SEA
GULF OF ALASKA
COLD BAY
4
50°
172°
156°
140°

Fig. 80 Map of Alaska. Numerals refer to regions described in Table 1.

Table 85 Coastal ecosystems in Alaska with example locations (listed in approximate order of importance).

Types Found	Example Location
Region 1. Southeast Alaska Estimated miles of tidal shoreline = 30,000 = 63% of Alaska Number of types = 21	
Glacial Fiords	Glacier Bay
Turbidity Fiords	Glacier Bay
Rocky Sea Fronts	Sitka
High Velocity Channels	Peril Strait
Medium Salinity Plankton Estuary	Auke Bay
Neutral Embayment and Shore Waters	Sea Otter Sound
Sheltered and Stratified Estuary	Port Frederick
Oligohaline System	Stikine River
Sedimentary Delta	Stikine River
Intertidal Rocks	Pleasant Island
Tide Pools	Pleasant Island
Worm and Clam Flats	Icy Strait
Kelp Beds	Icy Strait
Migrating Subsystem (salmon)	Little Port Walter
Eelgrass and Benthic Algae	Klawak
Bird and Mammal Rocks	Forrester Island
Marshes	Mendenhall Flats
Sewage Wastes	Juneau
Paper Mill Wastes	Silver Bay
Seafood Wastes	Petersburg
Pilings	Ketchikan
Region 2. Pacific Coast, Cape Spencer to Cape Elizabeth Estimated miles of tidal shoreline = 6,500 = 14% of Alaska Number of types = 22	
High Energy Beaches	Cape Suckling
Rocky Sea Fronts	Granite Cape
High Velocity Channels	Bainbridge Passage
Glacial Fiords	Unakwik Inlet
Turbidity Fiords	Columbia Glacier
Medium Salinity Plankton Estuary	Valdez Arm
Neutral Embayment and Shore Waters	Montague Strait
Sheltered and Stratified Estuary	College Fiord
Oligohaline System	Copper River
Sedimentary Delta	Copper River
Intertidal Rocks	Montague Island
Tide Pools	Montague Island
Worm and Clam Flats	Orca Inlet
Eelgrass	Redhead Lagoon
Marshes	Redhead Lagoon
Kelp Beds	Montague Island
Migrating Subsystem (salmon)	Olson Bay
Bird and Mammal Rocks	Montague Island

Table 85 (cont')

Sewage Waste	Cordova
Seafood Waste	Seward
Multiple Stress (earthquake) Beach	Montague Island
Pilings	Valdez

Region 3. Cook Inlet
Estimated miles of tidal shoreline = 400 to 500 = 1% of Alaska
Number of types = 9

High Velocity Channel	Forelands
Sedimentary Delta	Knik Arm
Oligohaline System	Turnagain Arm
Worm and Clam Flats	Cook Inlet
Migrating Subsystem (salmon)	Kachemak Bay
Sewage	Anchorage
Petroleum Shores	Kalgin Island
Pilings	Anchorage
Multiple Stress (ice, oil, tides)	Cook Inlet

Region 4. Kodiak Island, Alaska Peninsula, and Aleutian Islands
Estimated miles of tidal shoreline = 1500 x 5 = 7500 = 16% of Alaska
Number of types = 18

Rocky Sea Fronts	Aleutian Islands
Bird and Mammal Rocks	Amak Island
High Energy	Unimak Bite
High Velocity Channel	Unimak Pass
Neutral Embayment and Shore Waters	Cold Bay
Medium Salinity Plankton Estuary	Kitoi Bay
Sheltered and Stratified Estuary	Kodiak Island
Migrating Subsystem (salmon)	Cold Bay
Worm and Clam Flats	Cold Bay
Kelp Beds	Shumagin Islands
Eelgrass	Kinzarof Lagoon
Marshes	Kinzarof Lagoon
Intertidal Rocks	Aleutian Islands
Tide Pools	Aleutian Islands
Seafood Waste	Kodiak
Petroleum Shores	Amchitka
Pilings	Kodiak
Radioactive Stress	Amchitka

Region 5. Bristol Bay to Bering Strait
Estimated miles of tidal shoreline = 1800 = 4% of Alaska
Number of types = 14

High Energy Beaches	Kudiakof Island
Sedimentary Delta	Yukon Kuskokwim
Oligohaline System	Yukon Kuskokwim
Migrating Subsystems (salmon, birds)	Bristol Bay

Table 85 (cont')

Eelgrass	Izembek Lagoon
Medium Salinity Plankton Estuary	Kvichak Bay
Ice Stress Coast	Norton Sound
Under Ice Plankton	N. Bering Sea
Marshes	Izembek Lagoon
Worm and Clam Flats	Izembek Lagoon
Bird and Mammal Rocks	Pribilof Islands
Seafood Wastes	Port Moller
Sewage	Nome
Dredgings	Norton Sound

Region 6. Bering Straits to Canadian Border
Estimated miles of tidal shoreline = 1000 = 2% of Alaska
Number of types = 13

Ice Stressed Beaches	Elson Lagoon
Sea Ice and Under Ice Plankton	Arctic Ocean
High Energy Beaches	Pt. Barrow
Multiple Stress Beaches (ice, light, salinity)	Kasegaluk Lagoon
Oligohaline System	Kotzebue Sound
Sedimentary Delta	Colville River
Bird and Mammal Rocks	Cape Thompson
Worm and Clam Flats	Kotzebue Sound
Sewage	Kotzebue
Marshes	Selawik Lake
Eelgrass	Shishmaref
Kelp Beds	Wainwright
Radioactive Stress	Kotzebue Sound

Intertidal fauna of the Bering Sea is very poorly known. The estuaries and lagoons of Bristol Bay have received some attention. Malick, et al. (1971) noted that worms and clams were the dominant invertebrates in soft mud substrates.

In Bristol Bay and areas to the north, ice plays an important role in intertidal development. According to Menzies, et al. (1973), ice covers, ice scour, and ice grinding generally make the Arctic intertidal zones inhospitable to colonization by forms that are intertidal elsewhere.

The first major American study of Arctic biology in the coastal zone was done by MacGinitie (1955) at Point Barrow. Although he did not determine the dominant species of the community, he found 428 species of animals in the zone from 0 to 65 meters. The intertidal region was barren, but MacGinitie found the region below ice cover to be populated with those organisms shown in Table 86.

Zenkevitch (1963) found the effects of ice diminished rapidly below about 10 meters. Below this depth the biological communities were comparable to shallow seas. Table 87 lists the biomass and relative proportion of invertebrate groups living under the ice cover. Table 88 lists the macrophyte algae from a kelp bed in the Arctic coast. Because algae apparently can survive very low temperatures, the greatest hazard to the marine plants is the scouring by ice rather than

Table 86 Sublittoral invertebrates in order of relative abundance on soft bottoms near Point Barrow (from MacGinitie, 1955).

I. Infauna of Nearshore Mud Zone:

- Echiurus echiurus alaskanus (echiuroid worm)
- Arenicola glacialis (polychaete)
- Myriotrochus rinki (sea cucumber)
- Antinoe sarsi (polychaete)
- Melaenis lovenis (polychaete)
- Harmothoe imbricata (polychaete)
- Hamingia arctica (echiuroid worm)
- Halicryptus spinulosus (priapulid worm)
- Burrowing anemones (2 species)
- Burrowing tunicates (2 species)
- Mya truncata (clam)
- Mya japonica (clam)

II. Infauna of Outer Shore Mud Zone:

- Cerianthus sp. (burrowing anemone)
- Macoma calcarea (clam)
- Astarte montaqui (clam)
- Myriotrochus rinki (burrowing sea cucumber)
- Nucula tenuis (clam)

III. Epifauna of the Mud Zone:

- Foraminifera
- Dulichia porrecta (amphipod)
- Pagurus splendescens (hermit crab)
- Pagurus trigonocheirus (hermit crab)
- Hyas coarctatus alutaceus (crab)
- Serripes groenlandicus (clam)
- Liocyma fluctosa (clam)

Table 87 Biomass of sublittoral benthic invertebrate groups on the Siberian coast of the Chukchi Sea (from Zenkevitch, 1963).

Invertebrate Group	Biomass g/m^2	Relative Proportions
Polychaetes	35.2	16%
Crustaceans	31.8	15%
Echinoderms	16.2	7%
Gastropods	2.0	1%
Lamellibranchs	114.6	53%
Others	14.4	7%
Total	214.2	

Table 88 Macrophyte algae collected from kelp bed on arctic coast of Alaska (from Mohr *et al.*, 1957).

Brown Algae

Phyllaria dermatodea
Lominaria saccharina
Desmarestia viridis

Red Algae

Turnerella pennyi
Phytilophora interrupta
Antithamnion americanum
Phycodrys sinuosa
Polysiphonia arctica
Odonthalia dentata
Rhodomela lycopodioides f. flagellaris

the cold temperatures. Zenkevitch (1963) cited the lack of a hard substrate for attachment as the most crucial factor restricting the distribution of macrophytes in Arctic Alaska.

c. Resources of the Coastal Zone

Alaska Region

(1) Land Characteristics

The coast of Alaska covers a broad geographical range in latitude and longitude and includes every type of coastal system found in the lower 49 States with the exception of a semi-tropical regime. The 46,300-mile length of tidal shoreline includes islands, inlets and all shoreline to the head of tidewater. In the northern area the land/water interfaces are predominantly earth banks behind narrow pebble beaches all along the Arctic Ocean. The earth banks range from two to three feet above sea level east of Barrow to 30 or more feet west of Wainwright. Barrier beaches occur in several localities but they are low, without vegetation, and are covered with ice during the winter. These beaches are generally all pebbly.

In the Chukchi Sea and the northern Bering Sea areas, the seacoasts are largely low gravel banks, with areas such as Point Hope extending far out into the sea. Beaches are pebbly with little or no vegetation on them. Banks behind are low, gravelly, and slope upward to the steep hills gradually, often for many miles.

The vast Yukon-Kuskokwim delta area is a large marshy, low tundra which has an indefinite coastal boundary changing with river meander movement and tide cycles. The Aleutians are generally solid rock, steep-sided islands with a characteristic wet-tundra vegetation found nowhere else in Alaska. The coast of the Gulf of Alaska and Kodiak Island is predominantly rocky and steep with thin soils. The topography of the southeastern Alexander Archipelago area was established by the Pacific Mountain system, greatly modified by the erosive action of glaciers. These coastal edges are generally rugged with flat land occurring only in short reaches at river mouths and valleys left by retreating glaciers. Of the 47,300 miles of tidal coastline, 20,250 miles are classified as ocean shoreline exposure with the remaining 27,050 miles being bay or estuary shoreline exposure. The proportion of the total shoreline categorized as beach is undetermined. (For a generalized portrayal of the coastal landforms of Alaska, see the National Atlas of the United States "Coastal Landforms" Map, Scale 1:7,500,000, pp. 78-79 (1967).)

(2) Land Ownership

Approximate amounts of shoreline ownership are shown in the table below. However, ownership is in flux, and redistribution is underway under the provisions of the Alaska Statehood Act (P.L. 85-508) and the Alaska Native Claims Settlement Act (P.L. 92-203). It appears that a very small portion of the coastline will be in private ownership other than native (Eskimo, Aleut, Indian). Pending the establishment of entitlement under ANCSA, the ownership of long stretches of coastline are still indefinite. Further limiting the availability of land for general purposes are withdrawals for the Federal lands systems--National Parks and Monuments, Wildlife Refuges and Ranges, National Forests--and the Naval Petroleum Reserve. The major portions of state-selected shorelines are on the north slope of the Brooks Range, the north shore of the Alaska Peninsula and the shoreline of the Gulf of Alaska, as well as lands adjacent to the major coastal cities.

TABLE 89

SHORELINE OWNERSHIP IN ALASKA

	Federal	State/Local	Private	Total Miles
Ocean Shoreline	17,650	2,500	100	20,250
Estuary Shoreline	23,700	3,000	350	27,050
TOTAL	41,350	5,500	450	47,300

(3) Land Use

The Alaska shoreline is generally devoid of habitation or capital improvement except in the areas of the five major coastal cities of Anchorage, Ketchikan, Juneau, Kodiak and Kenai and the remaining smaller coastal cities and native villages intermittently situated along the entire coast length. Most villages are small ranging in size from less than 100 to generally less than 500. Coastal development, as shown in the table below, is less than one percent of the total shoreline length and consists mainly of private homes, with commercial development existing in only the major cities and villages. The only private shoreline development which is not city and village areas is in the Cook Inlet area, along which homesteading has evolved. Only 5 miles of the total shoreline is classified as public recreation, and consists of city parks in a few of the major cities.

TABLE 90

SHORELINE USE IN ALASKA

	Public Recreation	Private Recreation	Non-Recreation Developed	Undeveloped
Ocean Coastline	2	0	180	20,068
Estuary Coastline	3	0	150	26,897
TOTAL	5	0	330	46,965

The Alaska coastal cities and communities account for 61 percent of the State's total population. The Cook Inlet-Resurrection Bay area has 49 percent; 38 percent reside in the eastern Gulf of Alaska coastal areas, southeastern and interior Alaska; and 13 percent in the Arctic Coast, northwestern and western Alaska, Bristol Bay and the Aleutian Islands area (U.S. Bureau of the Census, 1971).

Land use varies in intensity and type from one coastal area to another. In the northern, western, and southwestern and Aleutian Islands area, land use is generally limited to subsistence and commercial hunting, fishing, trapping and gathering from both marine and terrestrial systems. Land use in the Cook Inlet-Resurrection Bay area is by far the most intensive of all coastal Alaska. Uses are generally similar to that found in any metropolitan area of 150,000 to 200,000. Extensive oil and gas operations occur in this area, as well as lumbering, mining, commercial fishing and agriculture. Land use in the eastern and central Gulf of Alaska coast is restricted generally to the fishing and lumbering industries.

(4) Recreation Resources

The diversity of recreation opportunities makes the coastal zone of Alaska very important from a recreation resource viewpoint. The main attraction to Alaskan visitors is the undeveloped wild and rugged wilderness that this region possesses. The numerous lakes, streams and ocean fisheries in the coastal zone provide some of the best sport fishing available. All five species of the Pacific salmon, sea run Dolly Varden and steelhead trout are among the species of fish that can be taken by the sport fisherman. Hunting opportunities are numerous with ducks and geese, as well as large and small game animals. The rivers, lakes and protected marine waters in the coastal zone provide excellent opportunities for powerboating, float boating, sailboating and canoeing. Sightseeing opportunities are varied and numerous; many high quality scenic areas exist along the coastline and surrounding mountains. Geological features of interest include volcanoes, glaciers and fiords. Zoological features include a rich variety of bird life, many seabird colonies and concentrations of sea otter, sea lions and seals. Prehistoric and historic native sites, oil gold camps and Russian churches depict Alaska's cultural past.

The central Bering-Chukchi Platform is an offshore region of considerable archaeological interest. This shelf area was emergent during several periods of Pleistocene glaciation, and served as a land-bridge for Asian nomads who crossed over to North America during the latter stages of ice advance that occurred at least 12,000 years ago.

Five Federal recreation areas, all located in the lower part of the State, front on the coastal zone and give Alaska national recognition from a recreational standpoint. These five areas and their general locations are listed below.

Table 91

FEDERAL RECREATION AREAS IN ALASKA

Recreation Area	Location
Sitka National Monument	Alexander Archipelago
Glacier Bay National Monument	Gulf of Alaska-Alexander Archipelago
Tongass National Forest	Gulf of Alaska
Chugach National Forest	Gulf of Alaska
Katmai National Monument	Alaska Peninsula-Shelikof Strait

During the 1973 recreation season there were over 11,700,000 visits to Federal, State, and local government-operated recreation areas in Alaska, as indicated by regions in Table 92. The number of tourists who visited Alaska during this time was about 215,000 according to the Alaska Division of Parks. Because of limited access and population distribution in Alaska, at one time or another the majority of these recreation and tourist visitors would spend time in the coastal zone. Recreation land areas located in Alaska as of the end of FY 1973 totalled 10,884,294 acres. Table 93 indicates the acreage within each region and the capacity. Federal lands comprised 85 percent of the total recreation lands; State lands were 14.7 percent; and local and private areas were less than one percent.

TABLE 92

VISITS TO ALASKA RECREATION AREAS BY REGION, FY 1973

Region	Locally-Operated Areas	State-Operated Areas	Federally-Managed Areas
Southeast	72,836	85,465	1,657,500
Southcentral	2,173,165	541,021	2,656,858
Southwest	8,675	0	898,816
Interior	174,000	127,695	2,704,100
Northwest	0	0	600,912
Total-State	2,428,676	754,181	8,518,186

SOURCE: ALASKA DIVISION OF PARKS, 1973.

TABLE 93

ACREAGE OF ALL RECREATION LANDS IN ALASKA, BY REGION, AND RECREATION FACILITY CAPACITY (persons at one time), FY 1973

Region	Acreage	Facility Capacity
Southeast	2,811,225	13,450
Southcentral	2,989,270	50,548
Southwest	3,111,734	1,794
Interior	1,971,847	14,121
Northwest	218	331
TOTAL-Alaska	10,884,294	80,244

Source: Alaska Division of Parks, 1973

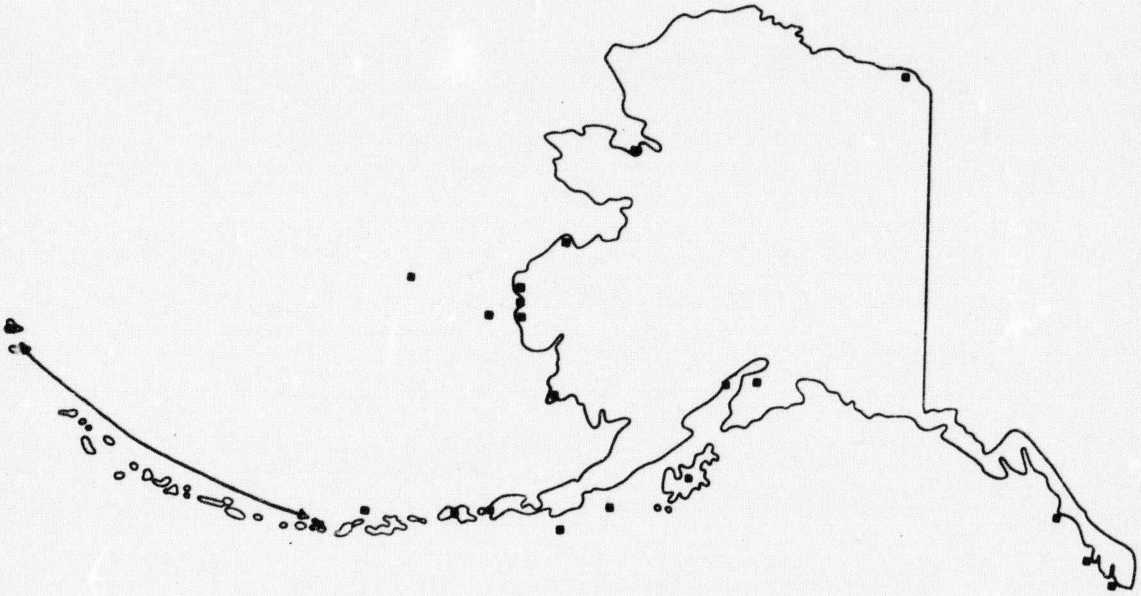
(5) Conservation Areas

Alaska is a major region important for the breeding, nesting and habitat of many species of game and birds. Presently, about 22,300,000 acres are devoted to wildlife conservation in the form of 18 Federal refuge areas, with additional areas provided by the State of Alaska. All of these areas front along the coastal zone. Their distribution is indicated on the accompanying map, and Table 94 indicates their general location and acreage (where available). In addition to wildlife conservation, these areas provide recreational opportunities as well as educational research.

(6) Transportation

Major Ports and Shipping

Waterborne commerce within, to, or from Alaska amounted to slightly over 23.5 million tons in 1971, representing



■ Federal wildlife areas

Figure 81 Federal Wildlife Refuges in Alaska

TABLE 94 FEDERAL AND STATE WILDLIFE-CONSERVATION MANAGEMENT AREAS IN ALASKA

Area	Location	Acreage
Forrester Island National Wildlife Refuge	Alexander Archipelago	2,832
Hazy Islands National Wildlife Refuge	Alexander Archipelago	42
St. Lazaria National Wildlife Refuge	Alexander Archipelago	65
Kenai National Big Game Refuge	Kenai Peninsula-Cook Inlet	1,730,000
Tuxedni National Wildlife Refuge	Cook Inlet	6,439
Kodiak National Big Game Refuge	Gulf of Alaska-SHelikof Strait	1,815,000
Semidi National Wildlife Refuge	Semidi Islands-Gulf of Alaska	251,930
Simeonof National Big Game Refuge	Simeonof Island-Gulf of Alaska	26,003
Izembek National Wildlife Refuge	Alaska Peninsula	320,802
Bogoslof National Wildlife Refuge	Bering Sea-Aleutian Islands	160
Aleutian Islands National Wildlife Refuge	Aleutian Islands chain	2,720,225
Cape Newenham National Wildlife Refuge	Bristol Bay-Kuskokwim Bay	265,000
Bering Sea National Wildlife Refuge	St. Matthew Island-Hall Island	41,113
Nunivak National Big Game Refuge	Nunivak Island-Bering Sea	3,330,630
Clarence Rhode National Wildlife Range	Yukon River Delta-Bering Sea	2,887,026
Hazen Bay National Wildlife Refuge	Yukon River Delta-Bering Sea	6,800
Chamisso National Wildlife Refuge	Kotzebue Sound	641
Arctic National Wildlife Range	Beaufort Sea	8,894,624
Pribilof Islands Seal and Otter Reserves	Bering Sea	
McNeil River Brown Bear State Refuge	Bering Sea	
St. Lawrence Reindeer Station	Bering Sea	
Cape Denbigh Reindeer Station	Norton Sound	

substantial annual increases over the 4.7 million tons moved in 1959 (Alaska Statistical Review, 1972). Although the increase has been rapid, it is useful to compare the tonnage to that of other areas. For example, Long Beach and Ventura, California, together had as much (98 percent plus) waterborne commerce as did the entire State of Alaska in 1972 (U.S. Army Corps of Engineers, 1972).

Employment in water transportation has declined significantly over the years, owing to greater capital intensiveness and general changes in the composition of market demand for transportation services. In 1960, 1,500 workers were employed in some facet of waterborne transportation; by 1971, this number had decreased to 800. In 1960, water transportation accounted for 30% of total transportation employment and dropped to less than 14% in 1971 (Alaska Statistical Review, 1972).

Over 50% of Alaskan waterborne commerce is petroleum products. Of this, 56% (8.3 million tons) is crude oil from the Cook Inlet. Additionally, about 7% of non-crude petroleum products are accounted for by the liquified natural gas (LNG) plant which exports its product from Cook Inlet to Japan.

Tables 95 and 96 summarize the passenger and freight traffic for 1972, as well as harbor usage by vessels and inbound tankers with 20-foot and over draft. The number of inbound vessels is slightly greater

TABLE 95

ALASKA PORT AND SHIPPING DATA - 1972

Major** Harbor	Controlling Depth (MLLW)	Psngrs.	1972 - Freight (1,000 Short Tons)
Metlakatla	25 ft.		291,331
Ketchikan	Adequate - 15 ft.	42,249	2,186,282
Wrangell	10 ft.	15,890	1,169,203
Wrangell Narrows	24-26 ft.	-	1,003,453
Sitka	22 ft.	11,147	1,243,437
Skagway	Adequate - 19 ft.	70,718	1,387.562
Valdez	20-50 ft.	-	253,505
Anchorage	28-35 ft.	2,342	2,058,199
Other Harbors			
Homer		7,052	170,382
Iliuliuk			190,109
Juneau		57,810	200,529
Kodiak		9,717	192,963
Petersburg		16,718	157,809
Other Southeastern		60,010	
Alaska Peninsula (South side)		632	12,399,786
Whittier		18,833	646,609
		313,118	23,551,159

**Includes only those harbors receiving 100,000 tons and over annually.
SOURCE: Waterborne Commerce of the U.S., 1972, U.S. Army Corps of Engineers, Part 4.

TABLE 96

HARBOR USAGE BY 20'+ DRAFT VESSELS - 1972

	Total	Tanker (Inbound)
Metlakatla	9	0
Ketchikan	55	40
Wrangell	41	0
Sitka	38	9
Skagway	147	4
Valdez	39	25
Anchorage	160	69

SOURCE: Waterborne Commerce of the U.S., 1972
U.S. Army Corps of Engineers, Part 4.

than outbound number because backhaul loads are sometimes not available and empty vessels are not counted.

Aviation Routes

Air transportation has employed more persons than any other type of transportation in the State. Average monthly employment in air transportation grew from 1,800 in 1959 (38 percent of total transportation employment) to 2,800 in 1971 (45 percent). It rose 55 percent over the 13-year period, averaging almost 7.2 percent growth per year over the last half of the period. Increased North Slope activity was responsible for much of the huge jump (24 percent) in air employment from 1968 to 1969, since employment in this sector nearly doubled in the Fairbanks area. Since 1969, air transportation employment had declined reflecting the reduction in activity north of Fairbanks.

Compared to the total population of the United States, Alaskans are exceedingly engaged in flying. On a per capita basis, Alaska has four and one-half times the number of licensed pilots as does the conterminous U.S. The number of eligible aircraft registered with the FAA in the State has grown steadily since statehood and topped 2,200 in 1970.

The preponderance of air operations and air carrier activity in Alaska emphasizes the underdeveloped status of other modes of transportation. Air transportation requires a relatively minor capital investment to provide reliable transportation services.

The operating costs of air transportation are relatively high, though, and the overall cost of air transportation tends to be higher than that of other modes when substantial quantities are moved. As alternate methods of transportation develop in Alaska, the predominant role of air transportation may tend to decrease. This is not to say that air activity itself will decrease. Air carrier will retain business where time-in-transit is of substantial importance (primarily, passengers and certain types of freight).

Railroad System

There are two railroads in Alaska--the Alaska Railroad (ARR) and the White Pass and Yukon Route (WP & YR). The ARR, built over the period 1914 to 1923, is owned by the Federal Government and operated under the Department of Transportation. The railroad extends from Seward north to Fairbanks, in the interior, passing through Anchorage, Mt. McKinley National Park, and a number of stations and towns along the way. Branches serve the agricultural area in the Matanuska Valley and the coal fields in the Healy River area approximately 100 miles south of Fairbanks. An additional spur connects the Port of Whittier on Prince William Sound. The WP & YR, owned by a Canadian corporation, has a terminal facility at Skagway, Alaska, and serves Whitehorse, Yukon Territory, and certain mining facilities in the Yukon (State of Alaska, Department of Economic Development, 1972).

Surface Transportation

The greater part of Alaska's Highway system is in the central and southcentral part of the State, roughly following the "railbelt" that was established earlier in the century. The highway system connects the Alaska-Canadian Highway built as a result of World Way II; in addition, the barge and ferry system provides a water-linked intertie for West Coast originating traffic.

While the highway system serves the greater part of Alaska's population, it exists in only a few of the State's geographic regions. The absence of landed surface transportation systems in Southeastern Alaska is due mostly to topography. The sparse population appears to be the principal deterrent for road systems in the northern, northwestern, western and southwestern areas of the State. The future development potential of these areas may be deterred by the lack of an adequate highway system.

(7) Historical and Projected Economic Growth in Alaska

This discussion of the "Economic Overview" is from Alaska Statistical Review, 1972, State of Alaska, Department of Economic Development, Division of Economic Enterprise, page 3 and 4.

> "From statehood to 1971, Alaska's economy achieved substantial growth and development. Alaska Gross Product (analogous to GNP, but on the State level) jumped from less than $720-million in 1960 to over $2 billion in 1971. Employment grew by more than 75 percent from 62,900 in 1959 to 110,600 in 1971. Income more than doubled from $410 million in 1961 to almost $1.1 billion in 1971. Over the thirteen year period, Alaska became less dependent upon federal expenditures as new industries emerged and existing industries expanded their economic activities.

> "Since 1969, oil and natural gas have replaced fisheries as Alaska's leading industry. While the fish and shellfish catch fluctuates widely from year to year and from region to region, the value to the producer and to the fisherman has increased substantially in the last year. Forest products has posted very steady gains in production value over the decade ($118 million in 1971) but continues to lag behind petroleum ($286 million) and fisheries ($199 million) as Alaska's third major industry. Tourism growth has been very rapid, particularly since 1967. Since the impact is felt throughout the supportive industries, employment attributed directly to Alaskan tourism is difficult to identify and measure. The growth in minerals (excluding oil and gas) is attributed to growth in demand for sand and gravel. While this industry holds great potential, its current impact is negligible compared to the four leading industries. Agriculture has consistently contributed about $5.5 million to the State's economy.

The tables that follow have been taken from "Annual Population and Employment Projections 1961-1980," State of Alaska, Department of Labor, Research and Analysis Section (March 1974). These tables indicate current and projected economic trends in the four coastal regions of the State, as outlined on the accompanying map.

The vast majority of the population in the northwest and southwest regions lives on the coast. In the southcentral region the majority of the population lives in the Cook Inlet Basin which includes the Palmer-Wasilla-Talkeetna, Anchorage, and Kenai Peninsula areas. The remaining population in southcentral Alaska is estimated at less than

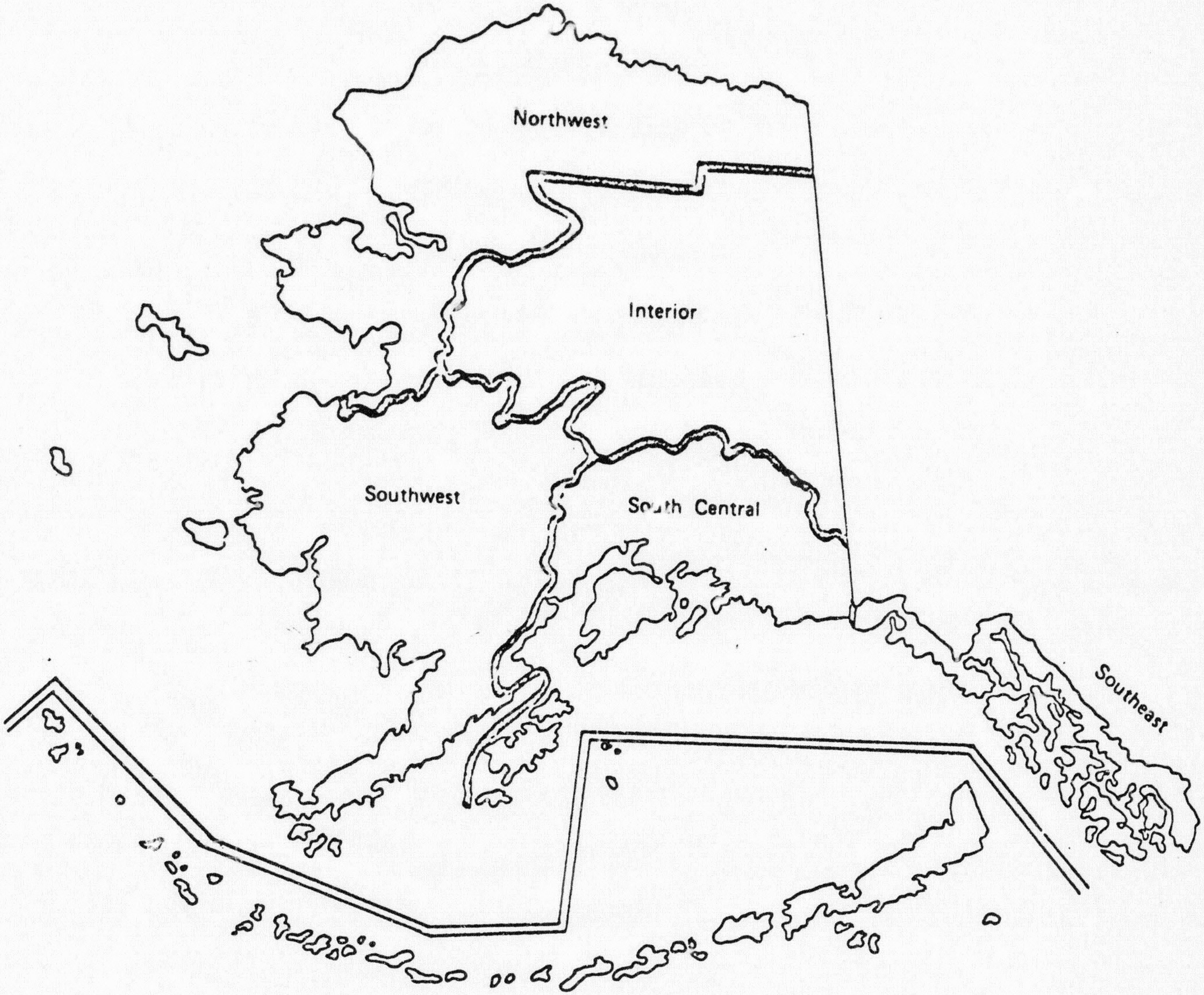

Northwest
Interior
Southwest
South Central
Southeast

Figure 82 ALASKA - Projection Regions

TABLE 97

ESTIMATED POPULATION AND EMPLOYMENT

NORTHWEST ALASKA

(All work force and employment data = 12 month average, in thousands of persons, for calendar year.)

	1961	1970	1972	1973	1974	1975	1980
Total Population (July 1)	12.7	13.3 1/	13.4	12.9	14.6	16.4	16.5
Total Civilian Work Force	2.8	4.5	4.7	4.8	6.8	8.4	8.8
Rate of Participation 2/	22.0%	33.8%	35.1%	37.2%	46.6%	51.2%	53.3%
Total Unemployment	0.6	0.6	0.7	0.6	0.7	0.7	0.9
Percent of Civilian W.F.	21.4%	13.3%	14.9%	12.5%	10.3%	8.3%	10.2%
Total Civilian Employment 3/	2.2	3.9	4.0	4.2	6.1	7.7	7.9
Self-Employed, Agriculture, Family Worker, Etc.	0.4	0.2	0.4	0.3	0.3	0.3	0.3
Government (Civilian)	0.6	1.1	1.6	2.1	2.3	2.4	2.9
Federal	0.5	0.6	0.7	0.7	0.7	0.7	0.7
State & Local	0.1	0.5	0.9	1.4	1.6	1.7	2.2
Mining	0.1	0.9	0.4	0.3	0.6	1.0	2.0
Contract Construction	0.1	0.5	0.3	0.2	1.4	2.3	0.6
Manufacturing	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Distributive	1.0	1.1	1.2	1.3	1.5	1.7	2.1
Trans., Comm., Public Util.	0.5	0.4	0.4	0.5	0.6	0.6	0.8
Trade	0.4	0.3	0.3	0.3	0.3	0.4	0.4
Finance, Ins., Real Estate	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Services & Miscellaneous	0.1	0.4	0.5	0.5	0.6	0.7	0.8

1/ Final 1970 Census Estimate adjusted to July 1, 1970.
2/ Rate of participation = Total Civilian Work Force divided by Total Population
3/ The Total Civilian Employment may not equal the sume of individual industry employment figures due to rounding.

TABLE 98

ESTIMATED POPULATION AND EMPLOYMENT

SOUTHWEST ALASKA

(All work force and employment data = 12 month average, in thousand of persons, for calendar year.)

	1961	1970	1972	1973	1974	1975	1980
Total Population (July 1)	22.6	27.0 1/	26.8	26.0	26.5	27.2	30.0
Total Civilian Work Force	4.6	6.6	6.8	7.1	7.4	7.8	10.7
Rate of Participation 2/	20.4%	24.4%	25.4%	27.3%	27.9%	28.7%	35.7%
Total Unemployment	0.6	0.9	1.1	1.0	1.1	1.1	1.5
Percent of Civilian W.F.	13.0%	12.6%	16.2%	14.1%	14.9%	14.1%	14.0%
Total Civilian Employment 3/	4.0	5.7	5.7	6.1	6.3	6.7	9.2
Self-Employed, Agriculture, Family Worker, Etc.	0.8	0.4	0.5	0.6	0.6	0.6	0.7
Government (Civilian)	1.2	2.1	2.4	2.8	2.9	3.0	3.6
Federal	1.0	1.3	1.4	1.6	1.6	1.6	1.7
State & Local	0.2	0.8	1.0	1.2	1.3	1.4	1.9
Mining	0.2	0.1	0.1	0.0	0.0	0.0	0.5
Contract Construction	0.2	0.3	0.3	0.2	0.2	0.2	0.5
Manufacturing	0.8	1.4	1.2	0.9	1.0	1.1	1.4
Distributive	0.8	1.4	1.2	1.6	1.6	1.8	2.5
Trans., Comm., Public Util.	0.3	0.3	0.3	0.5	0.5	0.5	0.8
Trade	0.2	0.4	0.4	0.5	0.5	0.6	0.7
Finance, Ins., Real Estate	0.1	0.1	0.0	0.1	0.1	0.1	0.1
Services & Miscellaneous	0.2	0.6	0.5	0.5	0.5	0.6	0.9

1/ Final 1970 Census Estimate adjusted to July 1, 1970.
2/ Rate of participation = Total Civilian Work Force divided by Total Population.
3/ The Total Civilian Employment may not equal the sum of individual industry employment figures due to rounding.

TABLE 99

ESTIMATED POPULATION AND EMPLOYMENT

SOUTH CENTRAL ALASKA

(All work force and employment data = 12 month average, in thousands of persons, for calendar year.)

	1961	1970	1972	1973	1974	1975	1980
Total Population (July 1)	115.9	164.9 1/	183.0	188.7	206.1	223.1	265.1
Total Civilian Work Force	38.5	63.8	74.4	79.2	88.6	96.7	115.6
Rate of Participation 2/	33.2%	38.7%	40.7%	42.0%	43.0%	43.3%	43.6%
Total Employment	3.1	5.2	7.6	8.1	10.9	11.9	11.9
Percent of Civilian W.F.	8.1%	8.2%	10.2%	10.2%	12.3%	12.3%	10.3%
Total Civilian Employment 3/	35.4	58.6	66.8	71.1	77.7	84.8	103.7
Self-Employed, Agriculture, Family Worker, Etc.	5.9	7.8	8.4	8.5	8.7	8.9	10.2
Government (Civilian)	13.2	18.4	20.9	21.4	22.5	23.5	28.4
Federal	9.6	10.1	10.1	10.1	10.1	10.2	10.5
State & Local	3.6	8.3	10.8	11.3	12.4	13.3	17.9
Mining	0.6	1.7	1.4	1.4	1.5	1.7	2.8
Contract Construction	2.0	4.1	5.0	5.2	6.9	8.6	7.4
Manufacturing	1.7	2.7	2.9	3.9	4.4	4.7	6.0
Distributive	12.0	23.9	28.3	30.7	33.7	37.4	48.9
Trans., Comm., Public Util.	3.1	4.6	5.3	5.5	5.7	6.1	8.4
Trade	4.7	9.9	11.2	12.0	12.9	13.8	17.0
Finance, Inc., Real Estate	0.9	2.1	2.6	2.9	3.2	3.3	4.3
Services & Miscellaneous	3.3	7.3	9.2	10.3	11.9	14.2	19.2

1/ Final 1970 Census Estimate adjusted to July 1, 1970.

2/ Rate of participation = Total Civilian Work Force divided by Total Population.

3/ The Total Civilian Employment may not equal the sum of individual industry employment figures due to rounding.

TABLE 100

ESTIMATED POPULATION AND EMPLOYMENT

SOUTHEAST ALASKA

(All work force and employment data = 12 month average, in thousands of persons, for calendar year.)

	1961	1970	1973	1974	1975	1980	
Total Population (July 1)	37.4	42.9 1/	44.8	46.4	49.3	53.4	66.9
Total Civilian Work Force	15.6	20.7	24.0	24.9	26.9	28.5	37.1
Rate of Participation 2/	41.7%	48.3%	53.6%	53.7%	54.6%	53.4%	55.5%
Total Employment	1.7	1.6	2.1	2.2	2.6	2.9	3.3
Percent of Civilian W.F.	10.9%	7.7%	8.8%	8.8%	9.7%	10.2%	8.9%
Total Civilian Employment 3/	13.9	19.1	21.9	22.7	24.3	25.6	33.8
Self-Employed, Agriculture, Family Worker, Etc.	1.9	2.2	2.4	2.4	2.5	2.5	2.9
Government (Civilian)	4.6	6.9	7.8	7.8	8.3	8.8	11.4
Federal	2.0	2.1	1.8	1.8	1.8	1.9	
State & Local	2.6	4.8	6.0	6.0	6.5	7.0	9.5
Mining	0.0	0.1	0.1	0.0	0.1	0.1	0.5
Contract Construction	0.6	0.7	1.1	1.4	1.4	1.2	1.8
Manufacturing	2.4	3.6	3.5	3.8	4.2	4.4	5.7
Distributive	4.4	5.6	6.9	7.3	7.8	8.6	11.5
Trans., Comm., Public Util.	1.6	1.7	2.0	2.0	2.1	2.2	3.0
Trade	1.4	2.1	2.4	2.7	2.8	3.1	3.8
Finance, Ins., Real Estate	0.2	0.3	0.4	0.5	0.5	0.5	0.7
Services & Miscellaneous	1.2	1.5	2.1	2.1	2.4	2.8	4.0

1/ Final 1970 Census Estimate adjusted to July 1, 1970.
2/ Rate of participation = Total Civilian Work Force divided by Total Population.
3/ The Total Civilian Employment may not equal the sume of individual industry employment figures due to rounding.

10,000 people that live along the coast. Although all of southeast Alaska is included in the table only a fraction of the people (approximately 3,000 to 4,000) are within the area covered earlier as the central and eastern Gulf of Alaska Outer Continental Shelf district.

The per capital personal income in Alaska has increased at a rate commensurate with that of the entire U.S. as indicated in the table below. The higher income level in Alaska reflects in part the higher cost of living within the State.

TABLE 101

PER CAPITA PERSONAL INCOME IN ALASKA AND THE U.S.

	1969	1972	% Change
Alaska	$4,219	$5,141	+21.9
U.S.	$3,708	$4,492	+21.1

(8) Commercial Fisheries in Alaska

The value of Alaska's 1973 commercial fisheries landings ($162,084,000) was larger than any other State (U.S. Dept. of Commerce, 1974a). Next to petroleum products, fisheries are Alaska's greatest source of revenue. Because of the size and history of Alaska's fisheries, a high level of public interest exists within the State regarding all aspects of fisheries policy.

A great potential for fisheries development exists in Alaska. In spite of the tremendous value of Alaskan fishery landings, foreign catches in oceans adjacent to Alaska are nearly ten times as great (poundage) as American catches. Ships of three countries (Russia, Japan, and South Korea) dominate these foreign fleets that concentrate in the Bering Sea catching herring, bottom fish (flounders, halibut), crabs (tanner and king), some demersal fish (Pacific Ocean perch, sablefish), and salmon.

Species of commercial fishes have already been discussed in a previous section (Active swimmers - Nekton, II.A.4.d.(4)), as to their relative abundance and value. Table 102presents the catch weight and value to fishermen in 1971 by regions. The regions are 1) Southeastern region, which includes the ports of Ketchikan, Petersburg-Wrangell, Sitka, and Juneau-Yakutat; 2) Central region, including the ports of Cooper-Bering Rivers, Prince William Sound, Resurrection Bay, Cook Inlet, Kodiak, Chignik, and those of the south peninsula; and 3) Western region, including the Aleutian Islands, North Peninsula, Bristol Bay, and the Arctic-Yukon. The dominance of salmon, in weight and value, is obvious from the table. Furthermore, coho, pink and chum salmon landings are usually much higher during even years due to the biology of the fish.

TABLE 102

1971 CATCH AND VALUE TO FISHERMEN, BY REGION
(From A.D.F. and G., 1972)

Species	SOUTHEASTERN Pounds	SOUTHEASTERN Value	CENTRAL Pounds	CENTRAL Value
Salmon:				
King or Chinook	4,528,834	$ 2,976,194	1,062,772	$ 389,560
Red or Sockeye	3,967,147	1,418,826	23,795,979	6,053,327
Coho or Silver	7,136,576	1,928,614	4,013,394	845,094
Pink or Humpback	34,414,077	5,231,120	51,702,552	8,270,327
Chum or Dog	16,095,008	2,536,503	29,282,200	3,906,834
TOTAL SALMON	66,141,642	14,091,257	109,856,897	19,465,142
Halibut	10,015,771	2,970,061	13,894,996	4,266,751
Herring	5,983,333	111,626	4,134,151	157,824
Herring eggs or kelp	—	--	769,481	384,741
Sablefish	573,472	95,160	21,345	3,223
Steelhead Trout	15,601	4,227	57	14
Bottom Fish	95,905	11,162	186,227	27,211
Other Fish	42,512	6,310	881	243
TOTAL MISC. FISH	16,726,594	3,198,546	19,007,138	4,840,007
TOTAL FISH	82,868,236	17,289,803	128,864,035	24,305,149
Crab:				
King	571,062	198,046	20,220,631	5,902,239
Dungeness	1,668,654	272,796	2,064,579	334,698
Tanner	251,082	25,108	12,463,005	1,326,833
Shrimp	959,787	95,245	93,931,517	3,813,800
Clams	—	--	243,121	70,152
Scallops, shucked	84,948	84,948	846,203	905,437
Abalone	923	2,077	--	--
TOTAL SHELLFISH	3,536,456	678,220	129,769,056	12,353,159
GRAND TOTAL	86,404,692	17,968,023	258,633,091	36,658,308

TABLE 102 (cont')

Species	WESTERN Pounds	WESTERN Value	TOTAL (all three regions) Pounds	TOTAL (all three regions) Value
Salmon:				
King or Chinook	6,380,288	$ 1,322,568	11,971,894	$ 4,688,322
Red or Sockeye	59,524,528	15,376,574	87,287,654	22,848,727
Coho or Silver	309,447	46,435	11,459,417	2,820,143
Pink or Humpback	143,138	16,407	86,259,767	13,517,854
Chum or Dog	9,349,112	1,093,045	54,726,320	7,536,382
TOTAL SALMON	75,706,513	$17,855,029	251,705,052	$51,411,428
Halibut	--	--	23,910,767	$ 7,236,812
Herring			10,117,484	269,450
Herring eggs on kelp	51,795	5,180	821,276	389,921
Sablefish	1,464	220	596,281	98,603
Steelhead Trout	--	--	15,658	4,241
Bottom Fish	--	--	282,132	$ 38,373
Other Fish	79,839	22,559	123,232	29,112
TOTAL MISC. FISH	133,098	27,959	35,866,830	$ 8,066,512
TOTAL FISH	75,839,611	$17,882,988	287,571,882	$59,477,940
Crab:				
King	49,911,412	$12,976,968	70,703,105	$19,077,253
Dungeness	16,196	2,430	3,749,429	609,924
Tanner	166,037	16,603	12,880,124	1,368,544
Shrimp	--	--	94,891,304	3,909,045
Clams	--	--	243,121	70,152
Scallops, shucked	--	--	931,151	990,385
[illegible]one	--	--	923	2,077
[illegible]L SHELLFISH	50,093,645	$12,996,001	183,399,157	$26,027,380
GRAND TOTAL	125,933,256	$30,878,989	470,971,039	$85,505,320

(9) Oil and Gas Resources, Alaska Region

The following estimates of oil and gas resources in coastal State waters are provided by the U.S. Geological Survey. USGS emphasizes that the estimates are speculative; only the maximum credible expectations are shown.

TABLE 103

CURRENT (1972) OIL AND GAS PRODUCTION FROM COASTAL STATE WATERS

(Oil in billion barrels; includes natural gas liquids)
(Gas in trillion cubic feet)

Area	Oil	Gas
Gulf of Alaska	0	0
Cook Inlet	0.1	0.1
Aleutian Shelf	0	0
Bristol Basin	0	0
Bering Sea	0	0
Chukchi Sea	0	0
Beaufort Sea	0	0

TABLE 104

ESTIMATES OF UNDISCOVERED RECOVERABLE RESOURCES IN COASTAL STATE WATERS*

(Oil in billion barrels; includes natural gas liquids)
(Gas in trillion cubic feet)

Area	Oil	Gas
Gulf of Alaska	0-2	0-10
Cook Inlet	0-1	0-5
Aleutian Shelf	0-1	0-5
Bristol Basin	0-1	0-5
Chukchi Sea	0-1	0-5
Beaufort Sea	0-1	0-5

---

* On March 26, 1974, the U.S. Geological Survey released estimates of the undiscovered recoverable oil and gas resources for broad areas of the OCS. Those estimates were based on statistical parameters of oil occurrences that apply only to broad geographic areas. It is entirely inappropriate to apply the same parameters to small, specific areas. The resource figures in the above table represent a general estimate, based on the above referenced information, of minimum and maximum volumes of oil and gas that might be recovered from the various OCS areas. It is statistically unsound to add the maxima and minima for an expectable range of resources for any larger area. New estimates have recently been prepared by the USGS for the undiscovered recoverable resources in OCS areas, and are discussed in the Description of the Proposed Action.

Table 105 Measured and Inferred Reserves in Coastal State Waters (December 31, 1972 Estimate)

(Oil in billion barrels; includes natural gas liquids)
(Gas in trillion cubic feet)

Area	Measured Reserves		Inferred Reserves	
	Oil	Gas	Oil	Gas
Gulf of Alaska	0	0	0	0
Cook Inlet	0.7	1.8	0-0.5	1-1.5
Aleutian Shelf	0	0	0	0
Bristol Basin	0	0	0	0
Bering Sea	0	0	0	0
Chukchi Sea	0	0	0	0
Beaufort Sea	0	0	0	0

The 1973 production from upland areas in Alaska, according to the American Petroleum Institute and American Gas Association, was 72,323,000 barrels of crude oil; 99,000 barrels of natural gas liquids; and 130,815,000,000 cubic feet of natural gas. These statistics exclude any production that may have occurred in the North Slope.

d. Existing Environmental Quality Problems in Coastal Zone

(1) Water Quality

Principal sources of pollution in Alaskan coastal waters have been from domestic sewage, industrial and commercial waste, forest industry waste, and waste or spillage from ships and small boats.

Most coastal communities in Alaska do not have sewage treatment facilities. The common method of disposal is to dump raw effluent onto beaches or into bays and harbors.

The seafood industry is one of the greatest polluters of Alaskan coastal zone waters. Of the many locations in the State that have one or more seafood processing plants, the greatest concentration of such plants is in the community of Kodiak on Kodiak Island. The 15 seafood processing plants near the city of Kodiak are presently disposing of wastes directly into the adjacent bay.

Provant et al. (1971) reported that in 1970, 14 of the seafood plants adjacent to the inner harbor area of Kodiak processed 110 million pounds of fish and shellfish and that an estimated 72 million pounds of waste were discharged into coastal waters. Over the years, this continued discharge of waste has affected the water quality and associated biological communities in the inner Kodiak harbor area. Sludge samples collected at Kodiak were extremely odoriferous. Samples taken near processor's outfalls did not contain any microscopic life forms. Provant et al. (1971) also reported that sludges containing partially decomposed processing wastes are frequently observed floating on the water and that they have a strong hydrogen sulfide odor.

Another major source of pollution to coastal waters of Alaska are commercial fishermen. Commercial fishing vessels are not equipped with sewage treatment facilities and are dumping human waste and other refuse directly into Alaskan waters.

At times as many as 100 seiners or gill netters will anchor in small coves. For example, before the start of the salmon season in the Cordova area as many as 700 fishing vessels will assemble near Egg Island to await the opening of the season. During these times routine maintenance is often performed on vessels. In most cases crank-case oil and oil filters are deposited overboard. It is also common practice on most fishing boats to deposit kitchen and human refuse overboard. The net result in the water and on surrounding beaches is quite noticeable.

There exists a mistaken idea that due to the motion of tidal currents and the mobile nature of water, the dumping of refuse in a small boat harbor is inconsequential. However, oil and other refuse discharged into harbors usually have little chance of being carried out to sea as they may accumulate in slips, wash up on the harbor shores, or be deposited on the harbor bottom. Petroleum products also have deleterious effects on paint and wooden hulls of vessels, docks, and other structures located in the harbor waters.

Offshore oil and gas production has contributed to water quality degradation in upper Cook Inlet in the past. There have been about 250 oil pollution incidents reported in Cook Inlet since 1962 and since 1965 there have been over 100 incidents attributed to offshore platform operations in upper Cook Inlet.

(2) Air Quality

Most of the air quality problems in the coastal areas of Alaska are in the Anchorage and Kodiak areas. The Anchorage area has a large number of unpaved streets with heavy traffic flow which creates a severe dust problem during the summer months (Mikkelsen, 1973).

In Kodiak the solid wastes discharged from seafood processors emit gases which can be detected throughout the downtown area. The floating sludge mats and the odoriferous gases emitted are aesthetically objectionable (Provant et al., 1971).

Air contaminants resulting from petroleum operations such as burning off sump pits and flaring from producing wells is being reduced in the area. Although flaring of waste gas is being phased out under Alaska State laws, platforms have pilot flames burning in the event of a blowout. The upper Cook Inlet oil production platform flare pilots have to be quite large to prevent being put out by strong winds in that area.

(3) Dredging Activities

Dredging activities in Alaska are currently at a minimum and pose little threat to existing environmental quality. However, if shipping in Alaska increases, dredging may become necessary to accommodate deep-draft vessels.

C. Description of Significant and Potentially Vunerable Resources

The following presentation was prepared by the U.S. Fish and Wildlife Service (FWS) for use in this EIS. It represents a compilation of current information on the various significant renewable resources in each of the 17 OCS regions. It is valuable in that it was prepared from a single viewpoint across all areas by the agency in the Department of the Interior charged with responsibility and jurisdiction for monitoring and protecting many of these resources. The resources listed and discussed do not comprise all the known resources in any region; they are the most significant resources from the FWS standpoint. They are all potentially vunerable to impacts from OCS oil and gas operations; potential impacts are discussed in Section III following. A summary table (Table 123) is presented in Section III for comparison with the area by area impact risk analysis.

A listing of threatened and endangered fauna (Section II.D.) follows the Fish and Wildlife Service presentation, and should be considered complementary material.

AREA BY AREA DESCRIPTION OF MAJOR FISH AND WILDLIFE RESOURCES

(Prepared by Fish and Wildlife Service)

1. North Atlantic

Georges Bank lies just off the coast of New England. The area of potential impact includes the bank proper and the coastal area from Long Island, New York, to the northeast part of Maine. The coast is rugged on the north, reducing gradually to nearly a plain from Boston south to Long Island. The area is noted for its lobsters, clams and scallops and very productive fisheries for bottom-dwelling or "groundfish". Considerable international fishing occurs for the latter on Georges Bank.

a. Fishery Resources

1. Commercial

The total commercial fish catch from Georges Bank, Rhode Island Sound and the Gulf of Maine by all countries, has averaged about 850,000 metric tons annually in recent years; approximately 25% of this total is harvested by U.S. fishing vessels (467 million pounds) and is valued (ex-vessel) at approximately $40 million annually. Annual value of the non-North American catch amounts to approximately $15 million in terms of American market values. Important or high-value fin-fish species caught by U.S. vessels include cod, haddock, yellowtail flounder, blackback flounder, gray sole and ocean perch.

Dock-side value of shellfish (mainly lobster, shrimp, clams and scallops) to coastal states from New York-Maine amounts to approximately $68 million annually.

Georges Bank is a major spawning ground for Atlantic herring, haddock, pollock, red hake, silver hake, American plaice, yellowtail flounder, gray sole and cusk. All of these species have planktonic larvae and, with the exception of herring, planktonic eggs.

2. Sport

In 1970, 1,666,000 salt water sport anglers from northeastern coastal states (Maine to New York) harvested 267,451,000 pounds of fish in coastal waters. Species caught in greatest numbers included bluefish, flounders, mackerel, puffers, striped bass and tautog. Sport harvest of clams and bay scallops, especially, is also significant though presently unquantified.

B. Wildlife Resources

1. Waterfowl

Over 300,000 migratory waterfowl winter along the coast between Long Island and Maine. Peak numbers are probably higher during spring and fall migration periods. Over one-third of the wintering population consists of scaup which characteristically "raft" in large numbers just offshore or on other large open water areas.

2. Other Birds

It is estimated that some 3.5 to 4 million other birds, including seabirds, shore and wading birds and coastal zone perching birds inhabit the North Atlantic region between Long Island and Maine during winter. Numbers are probably much higher in spring and summer. Comprehensive and precise population figures for birds generally do not exist. Very little work has been done on a regional basis on most major groups. Large seabird colonies utilize islands, particularly those offshore Maine and New Brunswick, and sandy shorelines of southern New England and New York for nesting.

C. Unique and Highly Productive Areas

1. Estuaries

It is generally agreed that the important commercial fishery on Georges Bank is intimately linked to the estuarine and near-shore shallow areas of coastal New England and New York. Probably up to 70% of the commercially important species of the Georges Bank fishery use these areas for spawning, nursery areas or summer feeding grounds for adults. The estuaries and near-shore shallows also produce the bulk of the region's shellfish and provide food and protective habitat for migratory birds and other wildlife. Extensive mud flats on the Maine coast are important producers of marine worms which are sold commercially as fish bait. There are many of these estuarine areas in the North Atlantic region, both large and small, extending from (and including) Machias, Frenchman and Penobscot Bays in Maine to Long Island Sound and Gardiners, Penconic, and Great South Bays on Long Island, New York.

2. Refuges and Management Areas

Within the coastal region between New York and Maine, there are 56 refuges, management areas, parks, sanctuaries, or other similarly designated areas which provide protective habitat or important feeding, breeding, or rearing areas for fish and wildlife. These are owned and administered by Federal, State and local governments and private interests.

2. Mid-Atlantic

The Baltimore Canyon area of the mid-Atlantic region is centered approximately within the area known as the Middle Atlantic Bight which includes the coastal and shelf areas between Nantucket shoals, off the Massachusetts coast, and Cape Hatteras, North Carolina. The area of concern extends from Long Island, New York, to the mouth of Chesapeake Bay and includes such important bays as the Chesapeake, Delaware, Barnegat, and Great South Bay of Long Island. These areas are well known for their contribution to commercial and recreational fisheries. Thousands of people earn their livelihood from the commercial fisheries, and millions participate in recreational fisheries. The area is in one of the most populated regions of the country.

A. Fishery Resources

1. Commercial

The total catch from New York to Virginia has been approximately 970 million pounds in recent years. Of this, 785 million pounds has been fin-fish; shellfish and related organisms have accounted for the remaining 191 million pounds. Annual value of the catch has been about $85 million ($23 million due to fin-fish and $62 million due to shellfish). The Middle Atlantic Bight area contributes about 20% of the U. S. lobster catch. Menhaden accounted for about 57% of the total weight of the fish catch and most of this was taken in Virginia waters. Oysters made up about 46% of the shellfish harvest and contributed about 25% of the dollar value.

The Middle Atlantic Bight area is a major spawning region for menhaden, scup, summer flounder, sea bass, bluefish and Atlantic mackerel. These species have planktonic eggs and larvae.

2. Sport

In the mid-Atlantic region (New Jersey to Cape Hatteras) in 1970, some 1,767,000 salt water sport anglers caught 246,267,000 pounds of fish. Spot, weakfish, bluefish, flounder, striped bass, mackerel and puffers were the species caught in greatest numbers.

B. Wildlife Resources

1. Waterfowl

Over 836,000 migratory waterfowl winter along the coast between Long Island and Cape Hatteras. Maximum numbers are higher during fall and spring migrations when inland birds and more coastal birds move through the area. Large concentrations of scaup "raft" in the nearby offshore areas and seaward reaches of coastal bays and estuaries. About 50% of the entire population of the prized canvasback duck overwinters in Chesapeake Bay. The Canada goose is especially abundant along the coast and estuaries of Delaware, Maryland, and Virginia during the winter.

2. Other Birds

Approximately 380 species of birds are currently reported from the area of concern. Over 5 million birds, including shore and wading birds and coastal zone perching birds, inhabit this region. Little is known about the seabirds in the Baltimore Canyon area. The common puffin, normally considered a more northern species, is fairly common, and gannets and black-legged kittiwake also occur in the area.

C. Unique and Highly Productive Areas

1. Estuaries

Most shellfish, and to a considerable degree, finned fish depend upon ecological conditions attributable to the presence of estuaries and associated shallow water inshore habitats. The well developed marsh systems in the mid-Atlantic region are suspected of playing a major role in the ecology of both sport and commercial fishes that use the estuary during at least part of their life cycle. Anadromous fishes, e.g., striped bass, white perch, shad, and alewife, depend critically on the estuaries as sites for spawning and early larval development. Several species that spawn offshore, e.g., menhaden, bluefish and weakfish use the estuaries as a nursery area. Many birds, especially Canada geese and ducks, use estuaries in the mid-Atlantic as major over-wintering areas.

2. Refuges and Management Areas

Within the coastal region between Long Island, New York, and Cape Hatteras, North Carolina, there are nearly 100 refuges, management areas, parks, sanctuaries, and other protective areas that are important feeding, breeding, and rearing areas for fish and wildlife. These areas are owned and administered by Federal, State, and local governments and private interests.

3. South Atlantic

The South Atlantic coastline, from Cape Hatteras to the Florida Keys, with its almost continuous fringe of barrier islands is comprised of an extensive series of beaches and protected, shallow sounds, bays, estuaries and marshes which provide essential habitat for some of the most valuable fishery and wildlife resources in North America. These resources furnish livelihood and recreation for countless thousands of American people. Of the 3,000 odd miles of coastal shoreline of the four southeastern states, some 2,650 miles are associated with estuarine and beach type habitats.

A. Fishery Resources

1. Commercial

In 1973, commercial fisheries of the South Atlantic states supported some 11,000 full-or part-time fishermen who harvested 220.7 million pounds of fish and shellfish valued at $54.1 million dollars. Of some 50 finfish species harvested, relatively few including menhaden, alewives, catfishes, snappers and groupers, mackerels, flounders, spot, croaker, mullet and kingfish comprised the bulk of the catch. The shellfish catch consisted mainly of shrimp, crabs, oysters, scallops, clams and lobsters.

2. Sport

In 1970, some 1.9 million salt water sport fishermen harvested 404 million pounds of fish from coastal waters from North Carolina to Florida. Species caught in greatest numbers were porgies, kingfishes, spotted sea trout, yellowtail snapper, spot, puffers, croakers, grunts, catfishes, bluefish and black sea bass. Surf fishing accounts for a substantial portion (34% in North Carolina) of the total marine sport fishing effort in this area. In addition, although undefined, sport use of shellfish species is very substantial.

B. Wildlife Resources

1. Waterfowl

The South Atlantic coastal area is utilized by some 867,000 migratory waterfowl annually. While some species are transient during fall and spring migrations, most remain in and are dependent upon the marine habitat throughout the winter. Canada and snow geese, black ducks, pintails, widgeon and coots frequent the shallow, protected estuarine and nearshore areas, and scaup and scoters and other "sea-ducks" frequently concentrate in large "rafts" offshore and in the "open" bays.

The hunting of migratory birds in the coastal zone constitutes a major activity which contributes substantially to the recreational industry of the South Atlantic. Some 79,000 duck stamps were purchased by hunters in the area in 1973.

2. Other Birds

Other migratory birds including doves, rails, snipe and gallinules use the marshlands extensively for nesting, rearing of young and feeding during the various seasons of the year. The diverse island beaches and marshes along the entire coast provide feeding, nesting and rearing habitat for a myriad of water-dependent and/or related shore, wading and marine bird populations. Ibis, egret and heron rookeries, and nesting colonies of terns, gulls and skimmers are numerous. The Florida Keys support the only known nesting colony of the magnificant frigate bird in the continental United States. Rookeries of the endangered eastern brown pelican, and the wood stork and roseate spoonbill (Florida endangered species) are present along the Florida coast.

3. Reptiles

The island beaches of the South Atlantic coast harbor the last substantial nesting population of the loggerhead sea turtle in this hemisphere. The endangered leatherback, hawksbill and Atlantic Ridley turtles are also reported to occur in this region.

C. Unique and Highly Productive Areas

1. Estuaries

The almost continuous estuary of the South Atlantic with its extensive salt marshes and inland lagoonal flats bordered by low lying islands and beaches and warm temperate character provides a diversity of habitat conditions which meet the requirements of and are essential to a host of fish, wildlife, and related biological resources. Virtually all of the important commercial and sport fin-fish and shellfish species are dependent upon this area during some period of their lives for spawning, development of juvenile stages, or feeding. Many are permanent residents of the nearshore and estuarine waters. In addition, the highly productive waters and associated wetlands are equally important to many migratory birds and other wildlife species which depend upon the marine environment for their livelihood.

2. Underwater Features

Rock outcroppings, coral reefs and other high relief undersea features are documented throughout the area. Though their extent and nature are inadequately defined, their potential value to both sport and commercial fisheries is recognized.

3. Refuges and Management Areas

Within this area, some 1.5 million acres of land are encompassed by conservation-management areas, including 17 coastal (310,000 acres) and five near-coastal (556,000 acres) National Wildlife Refuges which are managed exclusively for shore, wading and marine birds, waterfowl and other wildlife. Currently all or portions of six of these refuges are designated, and four proposed, as National Wilderness Areas. In addition, much of the privately owned marshland in coastal South Carolina (and to a lesser degree in Georgia and North Carolina) is intensively managed for, and significantly contributes to, the well being of migratory waterfowl populations in the Atlantic Flyway.

4. Eastern and Central Gulf of Mexico

The eastern and central Gulf are discussed together here because many important fish and wildlife resources are common to both areas. The area of concern extends from the Texas-Louisiana border to south Florida. The coastline from the Texas-Louisiana border to south Florida can be classified in two general categories: marshes and high energy beaches. Louisiana has broad marshes along its entire coastline with several barrier islands. East of Louisiana, the marshes are less extensive and the coastline becomes sand beaches and a series of bays as far as Apalachee Bay, Florida. A rocky shoreline and tidal marsh characterizes the Apalachee Bay to Anclote Key. Sand beaches, bays, tidal marshes, mangroves, and barrier islands make up the southwest coast of Florida.

A. Fishery Resources

1. Commercial

The most valuable fishery along the central and eastern Gulf coast is shrimp with an annual catch in excess of 100-million pounds, worth over $60 million. Oysters are important commercially in all four states, contributing $5 million to the economy of Mississippi, Alabama, and Louisiana, and $1.5 million to Florida.

Menhaden is the most valuable fin-fish, especially in Mississippi and Louisiana, with annual landings valued at $9.5 to $10 million. These figures do not reflect a severe drop in catch experienced in 1972, especially in shrimp landings, due to excessive freshwater from the Mississippi River. Red snapper is the most important species of fin-fish landed in Alabama and the second-ranked species in Mississippi. In Florida, mullet, red snapper, grouper, pompano, and Spanish and king mackerel are most valuable in that order.

Other species of commercial importance are croaker, red drum, spotted seatrout, flounder, thread herring, kingfishes, mangrove snapper, blue crab, stone crab, bay scallop, and sponges.

2. Sport

No comprehensive information is available that adequately describes sportfishing along this part of the Gulf. A 1968 survey of sport fishermen along the Louisiana coast estimated that salt-water sport fin-fishermen spent 4.045 million man/days and caught 24.27 million pounds of fish--eight times more than commercial landings of saltwater food fin-fish that year. The survey also reported 2.25 million man/days of sport crabbing with a catch of 29.25 million pounds and 0.373 million man/days of sport shrimping with a catch of 18.65 million pounds.

The 1970 Salt-water Angling Survey of the National Marine Fishery Services reported the following figures for the Eastern Gulf including the Mississippi Delta:

	Ocean	Sounds, Rivers, and Bays	Total
Number of Fishermen	633,000	915,000	1,548,000
Number of Fish Caught	43,352,000	146,536,000	188,888,000
Total Weight of Fish in Pounds	111,177,000	222,943,000	334,120,000

Sport shrimping and crabbing is also very popular along the coast of all four states and sport scalloping is common in several estuaries of Florida.

B. Wildlife Resources

1. Waterfowl

Migratory waterfowl are numerous throughout the east and central Gulf coast region during the winter with Louisiana having the greatest concentrations. A mid-winter population of 4,374,000 was estimated for the Louisiana coastal marshes in December, 1972, of which 84% were dabblers. The most abundant species were Gadwall, green-winged teal, baldpate, pintail, and mallard.

Actual bird counts during the winter of 1971-1972 tallied 23,549 waterfowl for St. Petersburg and Tampa and 4,122 for St. Marks National Wildlife Refuge, Florida. The lesser scaup is the most abundant waterfowl in this area with the red-breasted merganser second in saline environs.

2. Other Birds

Several other bird species are common or abundant along the coast from Louisiana to Florida although comprehensive population numbers are not known. Abundant species include the double-crested cormorant, little blue heron, common egret, snowy egret, Louisiana heron, wood stork, white ibis, American coot, black-bellied plover, five species of sandpipers, herring gull, ring-billed gull, laughing gull, royal tern, and black skimmer.

White and brown pelicans are common in some areas of Florida. The brown pelican seems to be increasing in numbers now in the northern Gulf. Pelagic species include Wilson petrel, gannet, sooty, tern, brown noddies, black tern, and three species of jaegers.

3. Reptiles

Several species of marine turtles occur in the eastern Gulf, including the Atlantic Ridley, hawksbill and leatherback.

The Atlantic green turtle and Atlantic loggerhead are observed regularly and their nests are found occasionally on barrier island beaches in the area.

The alligator, an endangered species, is common along the entire coast.

4. Mammals

The West Indies (Florida) manatee, an endangered species, is usually restricted to the area from the Suwannee River south in Florida.

The most abundant marine mammal in coastal and estuarine waters is the bottlenose dolphin, which is common along the entire coast in this region.

C. Unique and Highly Productive Areas

1. Estuaries

The Gulf coast of Louisiana, Mississippi, Alabama, and Florida contains over 6.3 million acres of open water estuaries, plus over 2.5 million acres of tidal marsh. Upwards of ninety percent of the commercial fish and shellfish caught along the northern Gulf are considered estuarine-dependent. The highly valuable shrimp fishery, for example, is intimately linked to estuaries. Shrimp are heavily dependent on nutrient-rich estuarine waters for post larval growth and development. These estuaries are also equally important to the valuable sport-fisheries, both bay and Gulf, and they provide essential habitat for waterfowl, sea birds, shore birds, and other wildlife.

The following table gives the approximate acreage of estuaries in the four states:

	Open Water	Tidal Marsh
Louisiana	3,378,924	2,000,000 +
Mississippi	500,379	66,933
Alabama	397,353	34,614
Florida	2,081,525	528,528
Total	6,358,181	2,630,075

2. Underwater Features

One of the most extensive and best known concentrations of reef areas in this region is the Florida Middle Grounds, located approximately 100 miles northwest of Tampa. These reefs support several types of coral, benthic algae and a diverse and abundant fish fauna, including many tropical and sub-tropical reef fishes. This area is one of the most intensively fished reef areas in the entire Gulf, particularly for snappers and groupers.

3. Refuges and Management Areas

Five National Wildlife Refuges totalling over 200,000 acres are located along the coast of Louisiana. That state also has three state-owned refuges totalling 176,000 acres and one private refuge on the coast. Florida has 13 National Wildlife Refuges along the Gulf coast. In addition, there are at least 30 State Wildlife Management Areas on or near the coast and Florida has designated 13 aquatic preserves. Three National Parks are located along this coast: Chalmette National Historical Park, Gulf Islands National Seashore, and Everglades National Park. Over 30 State Parks are within the coastal zone in the four states.

5. Western Gulf of Mexico

The Texas coastline is approximately 375 miles in length and is characterized by large estuaries and barrier islands. Approximately 1.8 million acres of estuarine waters are located in seven bay systems. These include Sabine Lake, Galveston Bay, Matagorda Bay, San Antonio Bay, Aransas Bay, Corpus Christi Bay and Laguna Madre. All of the systems except Sabine Lake are fronted by a 300 mile chain of barrier islands and peninsulas. These bays and coastal areas are extremely complex and productive ecosystems providing nursery, nesting, feeding, and resting habitat for numerous species of fish and wildlife. Approximately 400,000 acres of coastal saline and brackish marshes are located along the upper Texas coast from Sabine Lake to Aransas Bay. Submerged aquatic vegetation is characteristic of the central and southern bays from Matagorda Bay to Laguna Madre. There are approximately 150,000 acres of viable oyster reefs located in bay waters from Aransas Bay to Galveston Bay, with about two-thirds being located in Matagorda and Galveston Bays. Other important features along the Texas coast include open sandy beaches, rock jetties, mud flats, and offshore reefs.

A. Fishery Resources

1. Commercial

Texas coastal waters support several valuable fishery products with shrimp being the most important by far. Texas ranked fourth in the United States for 1973 in value of commercial landings. Average annual commercial fish harvest from Texas waters in recent years has consisted of nearly 100 million pounds of shellfish and 6.8 million pounds of fin-fish valued at $86 million and $1.8 million, respectively. White shrimp and brown shrimp have accounted for 90% of the shellfish catch, with oysters and blue crabs making up most of the remainder. The four most important fin-fish species in commercial landings are red drum, black drum, red snapper, and spotted sea trout.

2. Sport

The only comprehensive marine sport angler information available for the western Gulf is contained in the 1970 Salt-water Angling Survey of the National Marine Fisheries Service. That report contains the following figures for the western Gulf of Mexico from the Mississippi River delta to and including all of Texas:

	Ocean	Sounds, Rivers and Bays	Total
Number of Fishermen	341,000	477,000	818,000
Number of Fish Caught	47,173,000	50,535,000	97,708,000
Total Weight of Fish in Pounds	64,800,000	86,808,000	151,608,000

Species most sought by sport anglers are red drum, spotted sea trout, white sea trout, flounder, black drum, croaker, sheepshead and red snapper.

B. Wildlife Resources

1. Waterfowl

Most waterfowl species inhabiting this region are migratory, residing along the Texas coast during fall and winter. Some 400,000 geese, .7-1.8 million ducks and up to 150,000 coots winter in the region annually. Wintering waterfowl spend most of their time in the estuaries and marshes. Of the redhead duck population in the United States, 78% winters in the Laguna Madre area.

2. Other Birds

Wading and shorebirds also utilize the region's marshes and bays. Many are year-round or summer residents, nesting in coastal marshes and on rookery islands and feeding along beaches and in bays, marshes and other coastal waters. This group includes at least 26 species which are common in the area. Total numbers are unavailable, but this group together with sea birds, for which no population numbers are available either, probably ranges in the millions.

A small breeding population of the endangered brown pelican utilizes two known nesting sites on the Texas coast: Pelican Island in Corpus Christi Bay and Carol Island in Ayres Bay, between San Antonio Bay and Mesquite Bay. This remnant population, consisting of about sixteen birds presently, is the only known breeding population of brown pelicans along the Gulf coast west of the Mississippi River. The wintering population numbers from 125-150 birds.

The endangered whooping crane, whose total free-flying population consists of approximately 50 birds, winters on the Aransas National Wildlife Refuge.

3. Reptiles

Leatherback, hawksbill, Atlantic Ridley (all endangered) and green sea turtles occur in the region, but little is known of their distribution and abundance. Green sea turtles are believed to nest along the south Texas coast.

The endangered American Alligator is common along many parts of the coast.

C. Unique and Highly Productive Areas

1. Estuaries

The extensive estuarine system along the Texas coast constitutes one of the world's richest nurseries for fin and shellfishes and is a major wintering area for waterfowl and other birds. These estuaries are largely responsible for many of the region's outstanding and valuable fisheries. Over 90% of the U. S. fishery catch from the Gulf is made up of species that must spend part or all of their lives in these inshore waters. Crabs, shrimp and oysters are notable examples. Many fin-fish including notably sea trout, drum, sheepshead, spot, croaker, flounder and mullet are also estuarine dependent at some stage in their life cycle.

2. Underwater Features

High relief undersea features are common along the continental shelf offshore Texas. The Flower Garden Banks, located about 110 miles SSE of Galveston are the most prominent of a series of topographic highs in the northwestern Gulf. The flourishing coral reefs which cap these two banks are presently considered to be the northernmost thriving tropical shallow water coral reefs on the eastern coast of North America. Owing to their unique value as well developed coral reef communities, these reef areas are being considered for designation as marine sanctuaries under Title III of the Marine Protection, Research and Sanctuaries Act of 1972. These and many other less prominent highs in the northwestern Gulf serve as important feeding areas for snappers, groupers, amberjacks, and other marine fishes, and they are fished intensively by sport and commercial fishermen .

3. Refuges and Management Areas

Along the Texas coastal area there are five National Wildlife Refuges totalling 134,000 acres, which are managed for the conservation and protection of migratory waterfowl, shore and wading birds and endangered species, including eagles, falcons, whooping cranes and alligators. The Padre Island National Seashore which occupies 80 miles and 132,000 acres of Padre Island, also is a wintering area for migratory waterfowl. In addition, there are numerous refuges, wildlife management areas, parks, sanctuaries and other such areas in the region which are administered by state, local, and private organizations. These provide protective habitat and breeding and feeding grounds for fish and wildlife.

6. Southern California Borderland

This region occupies the coastal area approximately from Point Mugu southeastward to the Mexican Border. It includes the Channel Islands of San Nicolas, Santa Catalina and San Clemente. The region is about 170 miles long and approximately 75 miles wide. The area has many species common to the Santa Barbara Channel. Of the important commercial fisheries, albacore tuna dominate the catch in American waters. Numerous species of shore and seabirds occur in the region. Large marine mammals such as whales and porpoises are especially abundant. The favorable climate makes the area very attractive to marine recreational activities such as bird watching, scuba and skin diving.

A. Fishery Resources

1. Commercial

Total commercial fish landings in this region in 1971 (less tuna except albacore) were 161 million pounds valued at $1.6 million. Much of the tuna is harvested from Latin American waters. Shellfish landings totalled 10 million pounds valued at $.9 million. Of this total volume, 8.2 million pounds were squid valued at $150 thousand. Important commercial species for this region include most of the forms noted for Santa Barbara except oysters, dungeness crabs, salmon and various species of soles.

2. Sport

Sport fishing is an important activity in southern California marine waters. An index of this activity is shown by numbers of party boats: 225 boats operated with 4,681,000 anglers per year. There are no reliable statistics on shore anglers but it is believed that many hours are spent in shore angling.

It is well known that skin diving off southern California is practiced by many people. Exact statistics are not available, but the sport harvest by scuba and skin divers of fish and invertebrate animals is quite large.

B. Wildlife Resources

1. Birds

Since data are grouped for Santa Barbara and the rest of southern California, this group will be discussed for the entire area.

At least 180 species of waterfowl, shore and marsh birds are found in this coastal region. Seabirds, shorebirds, waterfowl, and songbirds use the coastal area and offshore waters during annual migrations. Many species of water-related nongame birds live along the coastal area and are an important factor in the aesthetic value of the region. These birds number in the thousands. Waterfowl habitat is limited and migrating birds remain only a short time. About 50,000 waterfowl wintered in the counties lying along this coastal region in 1974. Many species common to the shore and Channel

Islands outside of the Santa Barbara region are also important to southern California.

2. Reptiles

Several species of marine turtles occur in the area but quantitative data are unavailable.

3. Marine Mammals (see Santa Barbara discussion)

C. Unique and Highly Productive Areas

1. Estuaries

Only 8,500 acres of marsh and mudflats associated with estuaries remain in southern California, an area where nearly 90 percent of the original wetland acreage has been lost to a variety of developments.

There are 13 estuarine areas along the coast that warrant serious concern and many very small areas that have local significance. Most of the 13 areas are small compared to other coastal estuarine-wetland areas of the United States. However, their relative importance is probably very high due to their limited size and high use as a nursery grounds for many fin-fishes and shellfish and as resting and feeding areas for resident and migratory waterfowl and shorebirds. Four of these areas include Anaheim Bay (700 acres), Upper Newport Bay (1,000 acres), San Diego Bay (12,600 acres) and Tijuana River Estuary (1,175 acres).

2. Underwater Features

In recent years the kelp harvest in southern California exclusive of Santa Barbara has amounted to about 100,000 tons wet weight and its dockside value has been about $1 to $1.5 million. In this area the major beds occur around the Channel Islands and very near shore, especially off Pt. Dume, Long Beach to San Clemente and Long Beach.

3. Refuges and Management Areas

Within this area there are relatively few National Wildlife Refuges. Seal Beach National Wildlife Refuge is located on Navy property and covers a portion of Anaheim Bay. This is a productive shellfish and fish nursery area. Over 150 species of birds use Anaheim Bay. The endangered species, the least tern and the light-footed clapper rail are found on the refuge. Santa Barbara Island is a National Monument. Another National Monument includes Cabrillo-Point Loma near San Diego which is noted for unique tidal pools.

The other offshore islands, e.g., San Nicolas, San Clemente, and Santa Catalina have special ecological significance since they support abundant marine mammal and bird populations. Recreational use of these islands is high and includes bird-watching, scuba diving, sport fishing and boating.

7. Santa Barbara

The Santa Barbara Channel is an elongated feature located off the southwest California coast approximately 110 miles northwest of Los Angeles. The east-west length of the channel is about 70 miles, and the north-south length is about 25 to 30 miles. The total area is about 1750 square miles. It is bounded on the south by the Channel Islands of San Miguel, Santa Rosa, Santa Cruz, and Anacapa, and on the west by the open Pacific waters.

The Channel is especially rich in fish and wildlife. It is one of the major centers for the harvest of anchovies. There is a rich and abundant sea and shorebird fauna and marine mammals are especially well represented here.

A. Fishery Resources

1. Commercial

Total commercial fin-fishery landings at Santa Barbara in 1971 were 30 million pounds valued at $1.9 million. Two-thirds of this volume consisted of anchovies (20 million pounds valued at $.27 million). Other important commercial species include jack mackerel, rockfishes, and bonito with species of lesser importance including several soles, halibut and king salmon.

Shellfish less squid (6.7 million pounds valued at $.1 million) totalled 1.7 million pounds valued at $.7 million.

The Rock and Dungeness crabs, spiny lobster, oysters and abalone dominate the shellfish category.

2. Sport

A sizeable marine sport fishery exists in the Santa Barbara area. Angling for fin-fishes and gathering invertebrates for food are important pastimes. In the Santa Barbara Channel area, about 32 party boats operated during 1971 with about 59,500 anglers participating in the sport fishery. A sizeable but non-quantifiable shore angling fishery exists.

Statistics on the gathering of invertebrate food animals is difficult to assess. However, considerable clam digging and skin diving for fin-fish, abalone and spiny lobsters occurs. The pismo clam is the most important sport shell fishery.

B. Wildlife Resources

1. Waterfowl

Numerous waterfowl inhabit this area but the statistics are not easily partitioned between Santa Barbara and the remainder of southern California.

2. Other Birds

The Channel Islands provide the only major breeding area for huge numbers of seabirds such as western gulls, double-crested and Brandt's cormorants, xantus murrelets and brown pelicans. Quantitative information is sparse for these birds, but it is known that this area supports, in addition, a large concentration of seabirds including sea ducks, grebes, loons and fulmars.

There is an abundance of shorebirds in the area. About 50 species are known to occur at least seasonally in the area. The group includes many migrating species.

3. Marine Mammals

Marine mammals are a relatively large and diverse group in the area. There are probably at least 100,000 whales, porpoises and sea lions that occur near or inhabit the Channel Islands, and many occur in the Santa Barbara area. Seven species of baleen whales occur in this region. Shoreline, shelf, and continental slope forms occur as well as a few open Pacific species of marine mammals. The listing includes the harbor porpoise, grampus and Pacific right whale, blue, finback, humpback right whales. Strongly migratory forms include the gray, sperm, blue, humpback and pygmy finner whales. Other whales that may stray in the area include the false killer whale, spinner porpoise, and pygmy sperm whale and euphrosyme porpoise.

Large numbers and a wide diversity of Pinnipeds inhabit the Channel Islands. The northern elephant seal, the California sea lion, and harbor seal breed on the beaches and rocks of the islands. Also, the northern fur seal and Steller's sea lion occur in this area.

C. Unique and Highly Productive Areas

1. Estuaries

This area has few well developed estuaries and wetlands. Carpinteria Marsh (200 acres salt marsh), located about 10 miles south of Santa Barbara, provides feeding and resting area for numerous shore and marsh birds. The endangered light-footed clapper rail frequents this marsh. Goleta Lagoon (360 acres) serves as a fish nursery area, specially for the starry flounder. Numerous waterfowl, shore and marsh birds, including egrets, and the light-footed clapper rail inhabit this lagoon. Mugu Lagoon has ecologically important features similar to Goleta Lagoon.

2. Kelp Beds

In the Santa Barbara area, kelp, principally the giant brown kelp, grows in large beds where the substrate is rocky from the breaker zone to a depth of about 90 feet. About 69 square miles of kelp beds occur in the area. Kelp in certain areas is harvested commercially. About 130,000 tons are harvested annually of which 40% has come from the Santa Barbara area. These beds provide an excellent habitat for food and shelter to many pelagic and benthic organisms.

3. Refuges and Management Areas

Anacapa Island is part of the Channel Island National Monument. The island is inhabited by the endangered brown pelican. Other Channel Islands that are important as marine mammal and seabird habitats include San Miguel, Santa Rosa, and Santa Cruz. San Miguel is the most important of the islands for pinniped habitat.

More than 50% of the total population of sea lions in southern California inhabit the island. In addition, the island supports one of the largest known colonies of northern elephant seals and provides breeding grounds for the northern fur seal. Santa Catalina Island is noted for purple coral in the nearby waters.

8. Northern and Central California

The coastal boundaries of this region lie between the Oregon border on the north to approximately Point Conception on the south. The region is about 575 miles in length and encompasses a varied fish and wildlife resource.

The area is well known for its commercial fisheries, especially tuna, and most of the California salmon catch occurs here. Marine birds and mammals are a dominant feature of the wildlife resources. Numerous coastal embayments occur along the coast, and San Francisco Bay is the largest estuary system of the entire California coast.

A. Fishery Resources

1. Commercial

Total commercial fish landings in northern and central California in 1971 were 71 million pounds valued at $14 million. This included 20 million pounds of albacore tuna and virtually the entire California salmon catch (8 million pounds valued at $4.6 million). Shellfish landings excluding squid totalled 13.8 million pounds valued at $4 million. Squid landings were 16.6 million pounds valued at $.5 million. Fin-fish of significant economic importance for the region included anchovies, soles, sea herring, ling cod, perch, rockfishes, sablefish, tuna and salmon. Shellfish and other invertebrates of economic importance include dungeness crabs, shrimps, abalone, and oysters.

2. Sport

Significant offshore sport fisheries exist in northern California, but data on catch are not readily available. The latest ten-year annual average ocean catch of salmon in this zone is 150,000 fish, composed of 116,000 chinook and 34,000 coho salmon. The estimated minimum sport catch of salmon and steelhead combined in 1972 was 245,000 fish. The bulk of the chinook were taken by the San Francisco party boat fleet, while most coho were taken off the Eureka-Trinidad area. Abalone are taken by sport divers in quantities ranging around one to two million pounds annually.

B. Wildlife Resources

1. Birds

Most, if not all, of the waterfowl and shorebird species of the Pacific Flyway are found in this coastal region. Sea birds, shorebirds, waterfowl, and songbirds use the coastal and offshore waters during annual migrations. Nesting occurs on offshore reefs and rocks, rocky headlands, or marshy ponds adjacent to ocean beaches or tideflats. About 300,000 waterfowl wintered in the counties lying along this coastal region in 1974.

2. Marine Mammals

Marine mammals found on or near the coastal lands of central and northern California include sea lions, seals, sea otter, porpoises and whales.

C. Unique and Highly Productive Areas

1. Estuaries

Approximately 100,000 acres of tidal marshes and mudflats remain in central and northern California. This indicates a loss of about 70 percent since the turn of the century. Of California's remaining coastal wetlands, 25 have been given priority for acquisition based primarily on their fish and wildlife values and threats to their continued existence as a natural resource. Sixteen of these are located in central and northern California.

2. Refuges and Management Areas

Within the coastal region between Point Conception, California, and the Oregon border, 16 federal and state parks, refuges, reserves and other areas provide food, breeding grounds, and other habitat for fish and wildlife. All of these areas have been proposed by California as Areas of Special Biological Significance.

9. Washington - Oregon

Fish and wildlife resources and their habitats are diverse and varied along the coastal shoreline and continental shelf of Washington and Oregon. The region is characterized by a relatively narrow continental shelf and large inland bays or estuaries such as Puget Sound, Willapa Bay and Grays Harbor in Washington; Tillamook and Umpqua-Winchester Bays in Oregon; and the

Columbia River estuary which is shared by both States. These estuaries contribute significantly to the diversity and richness of the region's fish and wildlife resources.

A. Fishery Resources

1. Commercial

Commercial fish landings in the Washington-Oregon area for 1971 totalled 168 million pounds valued at $36 million. Of some 41 fin-fish species harvested, by far the most important resource was the salmon (72 million pounds). In order of poundage landed, the salmon species harvested were coho, sockeye, chinook, pink, and chum. Other principal species harvested offshore were flounders, rockfishes, albacore tuna (caught in the area during summer migration), hake, halibut, sea herring, ling cod, and ocean perch.

The shellfish catch (46 million pounds) consists mainly of Dungeness crabs (28 million pounds), ocean shrimp (10 million pounds), Pacific oysters (7 million pounds), razor clams, geoducks, and hard clams, and was valued at $12.7 million in 1971.

Commercial fisheries of the Washington-Oregon coastal area support approximately 17,500 fishermen. The value of the Northwest Pacific fishery products is almost 10% of the total for the United States.

2. Sport

Salmonids are the principal sport fish taken in the Washington-Oregon Zone. The annual sport harvest of coho, chinook, pink salmon and steelhead trout averages about 1.7 million fish. Other principal species of the sport harvest include flatfishes, croakers, cod, ling cod, rockfishes, sculpins and cabezon, smelts, surfperches, and striped bass.

In Washington, razor clams are a major sport resource, with an estimated minimum of 8.6 million harvested annually between 1967 and 1971. Dungeness crabs and bay clams also contribute to the sport harvest, and in 1972 approximately 500,000 sport fishermen landed 5 million pounds of shellfish valued at $3.8 million.

Oregon harvests of razor clams annually average about 160,000, and in 1971 about 1.8 million bay clams and 227,000 Dungeness crabs were taken.

B. Wildlife Resources

1. Waterfowl

Washington, Oregon, and California make up the Pacific Flyway for waterfowl in the United States. Virtually the entire coastal area, including harbors and offshore islands, is used by most, if not all, of the waterfowl and shorebird species found in the flyway. Each fall about 10 million ducks and one million geese use the flyway coming from their summer breeding grounds in Alberta, Saskatchewan, Alaska, the Yukon, and Northwest Territories to winter in the interior portions of California. About 100,000 waterfowl wintered in counties lying along the coasts of Oregon and Washington in 1974.

The Puget Sound area is primarily a resting and wintering area for ducks (345,000) and geese (49,200). Local production of Mallard and wood duck is approximately 60,800 annually.

2. Other Birds

Many of the sea birds originating in Siberia, Alaska, and Northwest Territories of Canada utilize the coastal waters of Oregon and Washington. Species with the largest numbers of migrants are the shearwaters and fulmars (tens of millions) which pass along the Pacific Coast on their seasonal migration from Alaska to their breeding grounds in the southern hemisphere.

Eighteen species of colonial sea birds number in the hundreds of thousands at the Oregon Islands National Wildlife Refuge.

During the 1973 fall migration and 1974 spring nesting periods, the peak population numbers on these islands were 980,000 and 180,000, respectively.

The Copalis, Flattery Rock, and Quallayute Needles areas are important for about 200,000 colonial nesting sea birds in addition to migratory waterfowl, shore birds, and song birds.

The San Juan Islands in the Puget Sound area support about 20,000 breeding glaucous-winged gulls. Other sea and shore birds nesting in the area are Brandt's and pelagic cormorants, tufted puffins, pigeon guillemots, Cassin's and rhinoceros auklets, black oyster catcher, and killdeer.

About 200 species of birds visit these islands annually. Large numbers of black brant use the extensive kelp beds of Smith Island as a winter feeding area.

The total breeding population of sea birds in the Washington-Oregon coastal zone including Puget Sound and San Juan Islands is approximately 1,656,000 (Washington 156,000; Oregon 1,500,000). In addition, there may be up to 500,000 non-breeding members of this population. Annual sea bird production has been estimated to be 480,000 individuals (Washington 80,000; Oregon 400,000).

3. Marine Mammals

Many species of marine mammals use habitat along the entire coast. North of California along the coasts of Oregon and Washington, the California sea lion becomes less abundant than the Steller sea lion, while the fur seal and harbor seal are abundant on smaller offshore rocks or islands which are important breeding areas along the northern part of the Pacific Coast. The northern sea lion is the most abundant mammal on the Oregon Islands. About 1,000 are observed annually.

Much of the shallow shelf surrounding the coastal wildlife refuges is used by the endangered gray and Pacific right whales. Near La Push, the area surrounding the central refuge waters and lands is the site of a sea otter transplant and the focal point of Washington State's otter propogation program. Destruction Island is a major harbor seal pupping area.

C. Unique and Highly Productive Areas

The coastal zone and offshore areas of Washington and Oregon are substantially different from other coastal areas of the United States. This region has certain features which are important to the environment of the Pacific Coast.

1. Bays and Estuaries

The Northwest Pacific Coast has very large numbers of phytoplankton (diatoms and dinoflagellates) during the spring and summer. These seasons are periods of coastal upwelling and terrestrial runoff which replenish nutrients to the surface waters. However, upwelling is not restricted to the summer months, although it is most intense during this period. The most important nutrient-laden fresh water source in the region entering coastal waters is the Columbia River. Phytoplankton generally are able to exhaust the nutrient supply from this river beyond 45 miles from the river mouth. Away from the influence of the nutrient plume of the Columbia River, chlorophyll concentrations are kept generally high inshore by upwelling in the summer and by coastal runoff in the winter.

Oregon's 14 major estuaries total slightly more than 56,000 acres - a relatively small amount and thus very valuable. Only three coastal States contain less estuarine area. Washington has two large estuarine areas on the southern half of its coast - Willapa Bay (70,400 acres) and Grays Harbor (61,400 acres). To the north lies the Puget Sound area with some 2,167 miles of shoreline encompassing 1.6 million surface acres including Puget Sound, Hood Canal and the eastern portion of the Strait of Juan de Fuca. This diverse marine environment produces a large variety of marine shellfish.

Estuaries and bays in this region are important as migration routes for anadromous fish (salmonids) and as nursery and spawning areas for forage fishes - herring, smelt, and anchovies. They are important to offshore hydrography (Columbia River) and to marine bird migrations because of their size. The large protected saltwater area of Puget Sound with extensive shoreline and shoalwater estuaries, mudflats, and marsh vegetation provides ideal feeding and resting areas for waterfowl including dabbling ducks (Mallard, teal, pintail, widgeon) diving ducks (scaup, buffleheads, scoters) and geese (snow geese, and western Canada geese).

A prime value of Oregon and Washington estuaries is the production of clams, oysters, and crabs for recreational and commercial uses.

2. Underwater Features

Kelp beds - One of the most important habitats along the Pacific Coast are kelp beds. These plants form an association for food and protection of numerous species of fish and invertebrates. North of Point Reyes, California, the bull kelp Nereocystis is the dominant genus.

Subtidal Rock Outcrops on Banks - Scattered along the Pacific Continental Shelf, usually near its outer edge, are shallow rocky banks rich with attached organisms and associated fish. Along the coast of Oregon the Hecata and Stonewell Banks are areas of this type.

3. Refuges and Management Areas

At present 29 islands totalling 367 acres along the Oregon coast are included in the Oregon Islands National Wildlife Refuge. The Neskowin Crest Research Natural Area, Cascade Head Scenic Research Area, and Oregon Dunes National Recreation Area, all administered by the U. S. Forest Service, have retained coastal and estuary associated habitat for various species of fish and wildlife. In addition, 72 federal, state county, and private parks and campgrounds are located along the Oregon coast. Many of these provide substantial amounts of relatively undisturbed wildlife habitat.

Flattery Rocks and Quillayute Needles National Wildlife Refuges comprise offshore islands extending south for 49 miles from Cape Flattery on the northwest coast of Washington. The Copalis National Wildlife Refuge consists of a series of small offshore islands extending along 23 miles of coast line north of Grays Harbor. These refuge areas include numerous offshore reefs, rocks, and rocky headlands which are important feeding and nesting grounds for many sea bird species and raptors.

Much of the upland area along this portion of the coast is part of the Olympic National Park. Willapa National Wildlife Refuge, located in south Willapa Bay, serves as a protected area for many sea birds, but more importantly for waterfowl, shore birds, and incidental big game, small game, raptors, and songbirds.

10. Gulf of Alaska

The northern Gulf of Alaska including Prince William Sound is an extremely varied and rich faunistic area. The relatively high and glacier-covered mountains which ring the area have resulted in a fauna virtually isolated from interior arctic influences and evolved toward a close association with the marine environment.

More than 140 species of mammals and birds inhabit the region as permanent or transient residents. An additional 70+ species, primarily birds, have been recorded as occurring in the area at one time or another.

A. Fishery Resources

Several commercial fisheries, foreign and domestic, occur in and around the proposed lease area. Otter trawl fisheries by Japan, Soviet Union, Korea and others harvest large quantities of Pacific Ocean perch, flatfish, and other demersal fishes. Longline fisheries are conducted for sablefish by the Japanese and for sablefish and halibut by the United States and for halibut by the Canadians. Salmon fisheries are conducted by U. S. nationals by trolling in continental shelf waters and by purse seining and gillnetting inside Prince William Sound and off the mouth of the Copper River. Pot fisheries by U. S. nationals for snow crab, king crab, Dungeness crab, and spot shrimp occur inside Prince William Sound and offshore for snow and Dungeness crabs. Limited dragging for Pandalid shrimp has occurred in past years. A dredge fishery for scallops is pursued by U. S. fishermen on the continental shelf, while razor clams are harvested by hand digging on the Cordova Flats.

During the five year period from 1967 to 1971 catches by all nations in the Gulf of Alaska averaged approximately 244,000 metric tons annually. More specifically, catches by American fishermen during 1969 to 1973 in the northeast Gulf and Prince William Sound totalled:

Species	Catch (lbs) $(x10^6)$	Value ($) $(x10^6)$
Salmon1/	121.8	30.8
Other Fish2/	31.9	8.4
Shellfish3/	29.3	5.0
Total	183.0	44.2

1/ 5 species

2/ includes halibut, herring, sablefish, bottomfish, cod

3/ includes king, snow and Dungeness crab, clams, shrimp

B. Wildlife Resources

1. Birds

Some individual bird species may number in the millions including migrants passing through the Gulf headed for breeding grounds to the west and north. Tens of thousands of shore birds and waterfowl remain in the area to rear broods on the Copper River. Thousands of seabirds (puffins, fulmars, shearwaters, petrels, etc.) are residents along the outer coast and some of the largest seabird rookeries in Alaska can be found on the outer islands. An estimate of sooty shearwater in the Barren Islands alone exceeds 2.6 million. Numbers of birds feeding on the Copper River Delta during the height of the migration may exceed 250,000 per square mile and during April and May more than 20,000,000 birds may use the area.

In spring, millions of pintails, dunlins, western sandpipers, and northern phalaropes move through the region, as do tens of thousands of whistling swans, snow geese, red knots, and sanderlings. Fall concentrations of whitefronted geese and sandhill cranes may exceed 100,000. Species with notably large summering populations include trumpeter swans (several hundred breeding pairs), Aleutian terns (150-250 breeding pairs on Copper River Delta), marbled murrelets (probably millions), and Kittlitz's murrelets (probably few 100,000's).

A large portion of the migratory waterfowl which supports hundreds of thousands of man hours and millions of dollars in sport hunting along the Pacific Flyway utilize this area twice each year for feeding and resting. Habitat degradation within this region could have a direct adverse impact on value and quality of sport hunting from Alaska to Mexico.

2. Marine Mammals

The sea otter population is presently estimated to number about 5,000 distributed among the islands and bays of Prince William Sound. Current estimates of populations in suitable locations elsewhere in the lease area; i.e., Yakutat, Icy Bay, Cape Yakataga, are unavailable, but sightings of otters in these waters have been reported.

Four large, historic sea lion rookeries are located within the approaches to Prince William Sound and population estimates of these animals range from 6,500 to 10,000. Total Gulf of Alaska population probably exceeds 46,000.

Harbor seals are abundant in nearly all the estuaries of the northern Gulf coast with largest numbers found on the Copper and Bering River deltas. Additional areas of concentration can be found at Dry Bay and in Yakutat. Estimated harbor sea population for the area encompassed by Prince William Sound southeast to Yakutat is between 15,000 and 20,000.

The northern fur seal, a marine mammal which suffered severe reductions in numbers by uncontrolled commercial huntings, has, through applied management techniques, been restored to levels which permit sustained harvests of up to 40,000 animals per year. These animals can be found feeding and moving throughout the northern Gulf of Alaska in numbers exceeding 50,000 during their spring migration. By late fall the population of approximately 1.2 million animals has moved back to its favorite feeding grounds over the continental shelves on both sides of the Pacific Ocean as far south as 32°N.

More than 20 species of cetaceans are known to frequent the northern Gulf of Alaska in varying numbers. These populations are probably at lower levels during the winter months since many of them migrate in response to the availability of a food supply. The Dall porpoise is considered one of the most abundant small cetaceans inhabiting the near-shore waters of Alaska. Total population estimates are unavailable but reports of several thousand have been made for the Gulf of Alaska.

C. Unique and Highly Productive Areas

1. Estuaries

This region has an extensive and complex estuarine system dominated by large bays such as Prince William Sound. These estuarine areas are highly productive of fish, birds, and marine mammals. A considerable amount of intertidal spawning by pink and chum salmon occurs in portions of Prince William Sound. This area produced two million pink Salmon in 1973, highest in Alaska. Crabs, clams, bottom fish and mammals are also abundant. The importance of the Copper River Delta and estuary may be noted from the discussion above. This is the most important migratory waterfowl area in the northeastern Gulf. In 1972, it had the third most important red salmon run in the state. Yakut Bay is an important migratory bird molting, nesting and loafing area. Resurrection Bay on the Kenai Peninsula between Prince William Sound and Cook Inlet is becoming the most important saltwater sport angling area in the State, primarily for coho salmon. It is also the site of a marine research station of the State of Alaska.

2. Refuges and Management Areas

There are no National Wildlife Refuges in the extreme northeast Gulf of Alaska. Several are located in the western Gulf, however, and these are discussed in the South Aleutian Section. Three other National Wildlife Refuges (St. Lazaria, Hazy Sound and Forrester Island) are located off the southeastern Alaska coast. The latter were established to protect sea bird colonies.

11. Cook Inlet

Cook Inlet is a major tide-mixed estuary extending from the heads of Knik and Turnagain Arms to the mouth between Cape Douglas and the tip of the Kenai Peninsula where it joins the Gulf of Alaska. Tides fluctuating nearly 40 feet between extreme high and low levels keep the water in constant motion, with currents over 6.5 knots. Winter ice forms in the upper Inlet causing large bodies of floe ice. Tidal currents together with floe ice causes some difficulty for winter shipping in the Inlet.

A. Fishery Resources

1. Commercial

Average annual commercial salmon harvest has totalled 21.5 million pounds in recent years; shrimp and crab catch has averaged 7.2 million pounds annually. A total of 733,893 pounds of salmon roe was processed in 1970. Additionally, 4808 tons of herring were harvested in 1970. The 1970 catch of fish and shellfish was valued at nearly $5 million.

2. Sport

Sport fisheries are intensively utilized throughout the region, largely by residents of the Anchorage metropolitan area. Available fish are Arctic grayling, Dolly Varden, Arctic char, lake trout, burbot, whitefish, black rockfish and the five species of salmon. Razor and other clam digging is pursued on the beaches of the Kenai Peninsula, and on the western shore of the Inlet at Kamishak Bay, one of the three authorized commercial razor clam areas in Alaska.

B. Wildlife Resources

1. Birds

Fifty-nine species of birds occur in Cook Inlet that make frequent use of salt water. Twenty-four additional species have been recorded that come into occasional contact with salt water, while 22 species make significant use of coastal marshes.

Primary waterfowl habitat lies in the Matanuska-Susitna River glacial outwash plain and the Kenai lowland. Trumpeter swans are one of the most important breeding waterfowl in the Cook Inlet area. Ducks and geese nest in lower numbers here than in interior habitats. During migration, as many as 70,000 waterfowl have concentrated in the Susitna River Valley.

Coastal areas support moderate populations of bald eagles and peregrine falcons.

More than 16 species of colonial nesting seabirds have been observed in the area. Two islands, Chisik and Duck, of Tuxedni National Wildlife Refuge, on the west side of the Inlet, provide nesting habitat for a variety of seabirds, including a vast black-legged kittiwake colony. Other suitable habitats are also located along the western shore. Pelagic forms such as fulmars, petrels and shearwaters are present during the summer season.

2. Marine Mammals

About 1,000 sea otters inhabit the west side of the Inlet from Shakun Rocks to Chinitna Point.

Several hundred to more than a thousand harbor seals may at times utilize Augustine and Shaw Islands, Kachemak Bay, and the entire west side of the Inlet to the Susitna River, and Sud Island in the Barren Islands.

Up to 10,000 sea lions can be found on the Barren Islands with pupping activity occurring in June and July.

Often as many as 400 beluga whales can be found in the Inlet. They sometimes move as far up the Inlet as the Susitna River and Ship Creek.

C. Unique and Highly Productive Areas

1. Estuaries

All of Cook Inlet is classified as an estuary. However, the bays and inlets of the lower section, which form subsystems of the main estuarine system, are the most valuable to fish and wildlife. Lower Cook Inlet is the spawning ground for many species of fish and shellfish and the habitat of many kinds of estuarine plants and animals. Kachemak Bay, near the end of the Kenai Peninsula, has been declared a critical marine area by the State of Alaska due to its importance as a shellfish nursery area.

2. Refuges and Management Areas

In addition to Tuxedni, mentioned above, the Kenai National Moose Range is located in this region. It occupies the western slopes of the Kenai Mountains and the glaciated lowland bordering Cook Inlet. Besides supporting moose and other mammals, this refuge contains nesting ground for the rare trumpeter Swan.

12. Southern Aleutian Shelf (Kodiak)

The Kodiak area supports the second most lucrative commercial fishing port in the United States. Seabird populations numbering in the hundreds of thousands can be found in and adjacent to the Barren Islands and along portions of the Kodiak and Afognak Islands coasts. The Kodiak region does not support the tremendous waterfowl populations found in many of the other potential lease areas.

A. Fishery Resources

During 1974, the fishing industry based at Kodiak delivered 112.9

million pounds of crab, shrimp, salmon and herring with a landed value of $29.1 million, ranking it second in the nation in value and eighth in volume. In addition, the small village of Chignik, on the Alaska Peninsula southwest of Kodiak and adjacent to the Kodiak lease area, produced salmon and shellfish to rank 16th in volume and 19th in value nationwide.

In 1966, over 90 million pounds of king crab were processed in Kodiak. Catches for the years 1969 through 1973 totalled:

	Catch Lbs. (x 10^6)	Value ($) (x 10^6)
Salmon 1/	191.0	30.6
Shellfish 2/	537.0	61.1
Other Fish 3/	28.0	8.0
Total	756.0	100.6

1/ 5 species

2/ includes king, tanner, Dungeness crab, shrimp and scallops

3/ includes herring, rockfish, bottomfish but not halibut

The National Marine Fisheries Service has estimated that the fishery resources of the Kodiak area can support a maximum sustained yield of 139 million pounds of shellfish and 190.5 million pounds of bottomfish annually.

Japanese, Soviet and Canadian fleets have been active in the proposed lease area since the early 60's. Recently, South Korean, Polish and Taiwanese vessels have also been sighted fishing in the vicinity. These fleets have taken thousands of metric tons of shrimp and bottomfishes from the area, primarily from the Portlock and Albatross Banks. In January 1975, 16 major Soviet vessels, 12 Japanese vessels and two Polish vessels were active in the area.

B. Wildlife Resources

1. Birds

Although migratory waterfowl use the Kodiak Island area to feed and rest, the region is not considered to be within a recognized flyway nor is it an important waterfowl production area. Wintering waterfowl populations within the Kodiak Island National Wildlife Refuge number about 200,000, however. Most-common species are mallard, pintail, goldeneye, scaup, widgeon and gadwall ducks and the emperor goose. Both bald and golden eagles are also resident.

Adequate seabird data are unavailable but more than 40 colonies exist in the area ranging up to colonies in excess of 100,000 residents. More-common species include kittiwakes, cormorants, puffins, gulls and murres.

2. Marine Mammals

Sea otters are not abundant about Kodiak Island although estimates of as many as 4,000 have been made for Afognak Island and some locations along the Alaska Peninsula.

Sea lion rookeries are located throughout the region from the Barren Islands to Chirikof Island. The sea lion population has been estimated at 37,000 for the Kodiak region.

Harbor seals are abundant about Kodiak and adjacent islands. The population has been estimated to be in excess of 15,000.

Fur seals can be found in abundance throughout the offshore area during spring and late fall as they migrate toward the Bering Sea. Likewise, a number of species of whales are known to pass through the area on their migratory travels to more northern waters.

A major portion of Kodiak Island has been classified as the Kodiak Island National Wildlife Refuge. This refuge was established to protect a population of one of the largest carnivores on earth, the Kodiak brown bear which has long been noted for its size and ferocity. Sportsmen from all over the world have hunted Kodiak for a chance at bagging one of these magnificant animals. The value of a Kodiak bear to an out-of-state trophy hunter has been estimated to be between $3,000 and $5,000 at current prices. The take of these animals yields $200,000 annually to the local economy. The Kodiak-Afognak bear population is estimated at about 2,000 within the refuge and 2,500 - 3,000 overall.

Bears feed on plant material during spring and summer, but the abundance of salmon is probably critical for development of fat stores for hibernation and production of viable young.

C. Unique and Highly Productive Areas

1. Refuges and Management Areas

Included in this region are five national wildlife refuges totalling 4.8 million acres. The Kodiak refuge is discussed above. Others include Semidi, Simeonof, Izembek (discussed below under Bristol Bay) and Aleutian Islands. Semidi consists of a group of islands located approximately 100 miles off the southwest end of Kodiak Island which support large seabird rookeries. A large sea lion rookery is located on the south end of the group. Simeonof, located in the Shumagin Islands south of the Alaska Peninsula, was established in 1948 to protect the growing sea otter populations in the Shumagins. The Aleutian Islands refuge includes 200 islands and extends 1,000 linear miles westward from the Alaska Peninsula. It is a multiple purpose area, providing sanctuary for numerous colonies of seabirds and a haven for sea otters. Unimak Island at the eastern end of the refuge supports the Alaska brown bear and caribou.

13. Bristol Bay, St. George and Navarin Basins

These three areas have been combined for this discussion, partially because of similarities in overall resources, but more specifically because the whole southeastern Bering Sea is a single, large ecological matrix due to prevailing current patterns. Bristol Bay estuary and associated continental shelf possesses the greatest concentration of birds, fish and marine mammals to be found anywhere on the North American continent.

The value of fish and wildlife in the areas adjacent to coastal Alaska have many times been emphasized. The fur seal and other marine mammals such as the gray whale, which breeds and feeds in northern seas then migrates to Mexico in the late winter to calve in the warm lagoons of Baja, California, are of international importance. Walrus, seal, and polar bears spend their entire lives in various parts of the Bering Sea or along the adjacent coastline. Many species of seabirds, including the shearwater which nests in the southern hemisphere and migrates by the million to the Bering Sea and vicinity during Alaskan summers, are also of importance internationally.

The biological heart of the Bering Sea complex is undoubtedly Bristol Bay, that part of the Bering Sea east of a line from the end of the Alaska Peninsula to Cape Newenham. This large estuary encompasses some 40,000 square miles or about as much area as the State of Virginia. The waters of Bristol Bay constitute one of the most biologically productive marine areas in the world. It has been estimated, for example, that approximately 7.5 x 10^6 MT of potential food exists in the benthos of the SE Bering Sea. Coastal lagoons along the southern shore of Bristol Bay are also highly productive and support some of the largest beds of eelgrass (Zostera) in the world. It has been estimated that some of these plant concentrations can produce as high as 8 g/m^2 of biological carbon per day.

The total area influenced by chemical, physical and biological processes active in the estuary is not limited to the Bay, however. Established current patterns indicate that occurrences within the estuary can have direct effect over broad areas far to the west and north of Bristol Bay which would include St. George and Navarin Basins. Conversely, activities at those locations could have significant impact on the resources of the Bay itself.

A. Fishery Resources

Shallow portions of the Bering Sea swarm with commercial fish and shellfish which are taken by many nations. Over the continental shelf offshore from Bristol Bay, literally billions of pounds of fish and shellfish have been harvested by both U. S. and foreign nationals for many years. Some stocks have been reduced by heavy foreign utilization, but concerted efforts by U. S. negotiators at international conference tables have gradually lowered foreign catches. Concurrently, U. S. nationals have increased their effort in the Bering Sea resulting in additional millions of dollars to the U. S. economy. Virtually 100% of the U. S. catch is processed into foodstuffs while much of the foreign catch is utilized for industrial purposes.

Sockeye salmon runs to Bristol Bay are the largest in the world. More than 50 million adult salmon have returned to spawn in the river and lake systems of this area in a single year.

The salmon fishery of Bristol Bay is an important element in the economy of the State of Alaska. In peak years, it is worth up to $20 million to the fishermen and $50 million to the salmon packing industry. A total of 13 salmon canneries are located in 8 different villages. There are additional plants for processing fresh-frozen and cured salmon and several firms also process salmon eggs.

During the period 1969 to 1973, catches by U. S. fishermen in the southeast Bering Sea and Bristol Bay totalled:

Species	Catch (lbs) (x 10^6)	Value ($) (x 10^6)
Salmon 1/	261.0	62.6
Other Fish 2/	1.3	0.5
Shellfish 3/	223.3	75.0
Total	485.6	138.1

1/ 5 species
2/ Herring, halibut, rockfish, bottomfish
3/ King crab, Tanner crab, Dungeness crab, shrimp

In addition to commercial fishing, sport fishing for chinook and coho salmon, rainbow trout, grayling, Dolly Varden and Arctic char is carried out in all the main streams emptying into Bristol Bay. During the spring, summer and fall, daily flights leave King Salmon for nearby sport fishing camps, where anglers catch trophy fish and ship them frozen to homes as far away as the East Coast.

B. Wildlife Resources

1. Waterfowl

Bristol Bay and the continental shelf area of the southeastern Bering Sea encompass one of the great bird concentration complexes of the world. The region is a cross roads for waterfowl coming from wintering locations as divergent as Japan and Mexico and headed for breeding areas as far east as Melville Island in northern Canada and as far west as the delta of the Lena River in central Siberia. Bristol Bay is the southern terminus of the "Arctic bird migration route". Additionally, birds from the "Asiatic Route", the "mid-Pacific Route", and the North American "Pacific Flyway" all funnel through this area.

Bristol Bay and the Alaska Peninsula coastal zone serve as more than just a way point on these extensive migration patterns since it is the last staging and feeding area for vast numbers of birds awaiting spring breakup in the Arctic each year. Likewise, birds fleeing the early Arctic freeze-up linger in this rich coastal environment for weeks to rest and feed before continuing their migration south.

Along the Alaska Peninsula, on the south side of Bristol Bay, are several large bays and near the southern tip, Izembek Lagoon, which has been designated the Izembek National Wildlife Range. These Bays are used twice each year by a major portion, or perhaps the world's entire population of black brant, cackling Canada geese, Steller's and spectacled eiders and by the North American population of emperor geese. In Izembek Lagoon alone, a count of only eight of the many waterfowl species which utilize the area exceeds one million birds. These, plus hundreds of thousands of common eiders, greater scaups, harlequin ducks, goldeneyes, gadwalls, scoters, snow geese and others can be found along the shores of Bristol Bay during the Spring and fall migration periods. In addition, large numbers of these birds remain within the general area to nest and rear broods.

Estimates of total numbers of waterfowl utilizing the region are highly variable as are the populations themselves. They undoubtedly exceed several millions annually. Many of the waterfowl, having evolved an absolute dependency on high quality Bristol Bay habitat, contribute substantially to sport hunting success and millions of dollars expended in that activity along the Pacific coast in Canada, the U. S. and Mexico.

2. Sea Birds and Shore Birds

Great as the abundance of waterfowl utilizing the estuary of Bristol Bay is, their numbers are far exceeded by those of the sea and shore birds.

Cape Newenham, on the north side of Bristol Bay, has some 20 miles of cliffs rising to 1,500 feet. In the summer, these cliffs are covered with nesting kittiwakes, murres, quillemots, auklets, and puffins. It is estimated that there are at least one million birds in this colony. Round Island and other islands in the Walrus Islands group also have huge bird colonies.

At Izembek Lagoon, nineteen species of shorebirds occur in varying degrees of abundance. Some of them, such as the rock sandpiper, least sandpiper, red phalarope, northern phalarope and ruddy turnstone frequent this Bay in the hundreds of thousands. Other embayments around the Bristol Bay estuary support similar numbers.

On the Pribilof Islands exists probably the largest murre colony in the world. At least a million murres, both common and thick billed, nest on St. Paul Island and far greater numbers are found on St. George. St. George Island also hosts a colony of least auklets which has been estimated to exceed an almost incomprehensible 3×10^7 birds. Enormous colonies of crested auklets, fulmars, horned puffins, tufted puffins, kittiwakes, cormorants and others also rely on the hospitality of the Pribilof Islands for population success.

It has been suggested that the almost unbelievable numbers of birds utilizing the Bristol Bay continental shelf and immediate uplands are a vital link in recycling nutrients contributing to the vast productivity of the Southeastern Bering Sea.

3. Marine Mammals

The Pribilof Islands, guarding the approaches to Bristol Bay, represent one of the world's unique ecological situations. The Northern fur seal, rescued from the verge of extinction by international cooperation and management, returns to these small islands to reproduce each summer. (A smaller number return to the Commander Islands in the western Bering Sea). The seal herd, numbering in excess of 1.5 million animals, winters along the west coast of the U. S. but returns to the

Bering Sea for the months of June to October. Here the females bear and nurse their pups, subsisting on the abundance of pollock and squid in the area. Here too, in some years, as many as 33,000 male seal skins are harvested, yielding several millions of dollars to the U. S. treasury and supplying employment to the entire Pribilof Island native population. Continuation of this resource on an optimum sustained yield basis can be readily maintained providing that the ecological situation remains relatively constant.

Sea otters may be found along the North Pacific coast and on the southern shore of Bristol Bay, as far north as Cinder River. Their numbers are estimated between 10 thousand and 15 thousand. Although the U. S. Fish and Wildlife Service now has jurisdiction over the sea otter, these animals will usually be found within the 3-mile state limit, except for occasional foraging activities on shoals and reefs further out. Sea otters are not known to make migrations of any magnitude and interchange between population centers is minimal. Consequently, otters are often restricted to relatively small geographic areas. Disruption of these restricted habitats by pollution or other disturbance could effectively eliminate whole segments of the overall population.

The Steller sea lion is abundant in the eastern Bering Sea and the Bristol Bay area. Their preference for rock habitat generally confines them to the northwest and southwest portions of the Bay. An additional aggregation can be found near the Pribilof Islands. Like the sea otter, they prefer relatively shallow water, but are sometimes found at sea far from land.

Survey information on Steller sea lions in eastern Bering Sea and Bristol Bay is minimal but population estimates approach 20,000 to 25,000 along the southwestern shore, 8,000 to 9,000 on the Pribilof Islands and 400 to 500 near Cape Newenham.

Harbor seals (sometimes referred to as "hair seal") are common throughout Bristol Bay. Harbor seals are less adapted to a land environment than sea lions and fur seals, and need gentle slopes to haul out. Consequently, these seals will usually be found on sand bars, beaches, and low rocks, especially along the southern coast of the Bay.

Harbor seals do not usually congregate in huge colonies as do fur seals and sea lions and generally remain in groups of 100 or less. Estimates of the population are unavailable, but their numbers in Bristol Bay probably range between 10,000 and 20,000.

Walrus are usually found along the edge of the ice pack; the herds found in Bristol Bay are at the southern limit of their range. Except for those bulls which remain in Bristol Bay, most walrus follow the ice pack as it recedes, hauling out on the edges of the polar ice pack in summer. Estimates of that portion of the entire walrus population utilizing Bristol Bay ice cover range between 15.7 thousand for low concentration areas to 34.4 thousand for high concentration areas.

Several whale species are known to occur in the Bering Sea, but population sizes are generally unknown. Beluga whales, which feed extensively on salmon, are quite common in Bristol Bay.

C. Unique and Highly Productive Areas

1. Refuges and Management Areas

Including Izembek and Cape Newenham, mentioned above, there are seven National Wildlife Refuges or Ranges in this region encompassing a total of 4.6 million acres. Others are Bogoslof, Nunivak, Hazen Bay, Clarence Rhode and Bering Sea. Bogoslof, in the Bering Sea 30 miles north of Umnak Island in the Aleutian Chain, has important sea bird rookeries, including one of the largest thick-billed and common murre colonies in Alaska.

Nunivak is in the Bering Sea 150 miles west of Bethel and is home of the only muskox herd in the United States. Coastal lagoons on the south side of the island are utilized as resting and feeding areas by brant and Canada geese during migration. Vast sea bird rookeries are on the sea cliffs of the western coast of the island. Hazen Bay and Clarence Rhode, on the Bering Sea coast, are migratory bird nesting areas. Clarence Rhode is the primary nesting area for the cackling Canada goose and the major nesting grounds of the black brant. Other geese, whistling swans and several duck species also nest here as well as Sandhill Cranes and numerous shore birds. The Bering Sea Refuge is 250 miles from the Alaska mainland, lying west of the Yukon-Kuskokwim Delta. Within this refuge is a colonial seabird nesting area 5 miles long. This rookery contains one of the largest fulmar colonies in the world, together with parakeet auklets, horned puffins, pelagic cormorants and thick-billed murres.

The unique values of the Bristol Bay estuary and the eastern Bering Sea are apparent from the foregoing discussion. In summary, this region is a highly productive ecosystem. Among its resources are internationally important salmon fisheries, as well as bottomfish and shellfish stocks. The area supports essentially the entire world population of some species of geese, spectacular populations of other birds, sea mammals, and riparian wildlife. Additionally, the economy of the entire Bay is based upon its fisheries and related subsistence resources.

14. Bering Sea (Norton Basin)

Most of the 25 species of Bering Sea marine mammals and 40 species of marine birds that frequent the Bering Sea are part time residents associated with the movements of the ice pack. Ice forms in November and persists until May. The sea ice provides a matrix of primary productivity, and functions as a living platform, breeding ground, climatic barrier and migratory route for Bering Sea mammals and birds.

Oceanic and coastal waters that would be affected by a Norton Basin OCS lease sale stretch from Cape Prince of Wales to Hooper Bay and include Norton Sound and the Lower Yukon. A majority of the thirty-two settlements located within the area are dependent upon the region's resources for subsistence.

A. Fishery Resources

1. Commercial

The commercial salmon fishery and subsistence fishery of Norton Basin are important elements in the economy of Alaska. Average annual commercial salmon catch for Norton Sound and the lower Yukon for 1961-1971 was over five million pounds valued at $627,000. The subsistence salmon fishery for the same period averaged 3.3 million pounds annually.

2. Sport

A variety of sport fishing opportunities are also provided by grayling, char, Dolly Varden, pike and salmon. Fly-in sport fishing is increasing in the region.

B. Wildlife Resources

1. Migratory Birds

The region contains several units of highly important migratory bird habitat. Fourteen of the 23 known species of Alcidae in the world occur in the Bering Sea. These and other "seabirds" spend most of their lives at sea, coming ashore only to breed. More than 50 species of other birds, not regarded as "seabirds", frequent the coastal waters and littoral zone, where they utilize marine resources on a seasonal basis.

The Seward Peninsula which contains several units of breeding habitat has a population of about 231,000 ducks. Density is about 60 ducks per square mile, higher than average for most habitat in western Alaska, except for the Yukon Delta.

Pintail and greater scaup are the most important species, forming about half of the population. White-fronted geese are present in significant numbers and remnant populations of emperor geese and black brant are present. Coastal lagoons are important during migration, providing the only significant sheltered waters along the coast between the Arctic and the Yukon Delta.

The Yukon Delta, with a total area of 26,000 square miles, is the largest and most productive of western Alaskan waterfowl habitats. The unit contains an estimated breeding population of about 1.3 million ducks which is projected to a fall flight of about 2.3 million. Nearly the entire population of emperor and cackling geese nest here and about half of the continental population of black brant. The entire Pacific Flyway populations of white-fronted geese, most of the Pacific Flyway whistling swans and some Taverner's geese nest on the Delta. Lesser snow geese occupy the delta during migration to or from breeding grounds in the USSR. A portion of the primary habitat for these species is preserved by the Clarence Rhode National Wildlife Refuge.

The Yukon Delta also contains large populations of shore and water birds. Arctic and red-throated loons are prominent nesting species, while lesser sandhill cranes are more abundant here than in any other Alaskan region. Smaller birds found in unique abundance include bar-tailed godwits, dunlins, western sandpipers, northern and red phalaropes, and black and ruddy turnstones.

Important seabird colony areas in the vicinity of the Norton Basin include St. Lawrence Island, Little Diomede Island, Fairway Rock, King Island, Sledge Island, Egg Island, Besboro Island, Cape Denbigh, Bluff, Rocky Point, and Cape Darby.

Aside from their intrinsic and esthetic values, marine birds of the Bering Sea have long been part of the Alaska Natives' culture as a source of food and clothing. Harvests of birds and their eggs by Alaskan natives probably exceeds 10 metric tons per year.

2. Marine Mammals

During winter, walrus, several kinds of seals, and whales move south into the region with the advancing sea ice. Other species move north into the region during the ice-free summer. Prorating their occurrence in terms of full time residence in the Bering Sea, the marine mammalian fauna is equivalent to 1.5 million full time residents.

Hair seal and bearded seal are very important to the coastal communities for subsistence; of lesser importance are the beluga whale and walrus.

15. Chukchi and Beaufort Seas

The Beaufort and Chukchi Seas, while dissimilar in some respects, have many similarities relative to exploration, development and potential impacts of petroleum production. Not the least of these similarities is the lack of knowledge of the Arctic marine environment in both areas. Detailed data collected to date is, at best, fragmentary. Some excellent work has been done at specific locations, i.e., Cape Thompson, Prudhoe Bay and Pt. Barrow, but great gaps exist over much of the coast from the Canadian border to Nome. Of all OCS regions, less is known about biological resources of the Beaufort Sea than any other.

Economic values for biologic resources are vitually non-existant since few of these currently enter the market place. Whales, seals, birds, and fish are still used as subsistence items by Arctic natives.

Rational development within these basins will necessitate cooperative efforts between conservation agencies, research groups and industry at a much higher level than might be expected elsewhere. This is imperative not only from the standpoint of the recognized fragility of the Arctic environment, but because of the international character of many of the potentially affected resources.

A. Fishery Resources

Fish inhabiting the freshwater and marine environments of the arctic coastal area are relatively few in species, restricted in distribution, and slow growing. Information concerning their abundance, distribution and life history is sparse. For instance, such essential matters as the growth rates of these fishes, their fecundity, the size of the stocks or rate of recruitment, or even whether the adults breed annually or less frequently are not known.

The majority of arctic marine fish species and their greatest numbers seem to occur in the Chukchi Sea although comparative data on the Beaufort Sea are lacking. Most marine fishes in the Arctic are demersal or benthic. Young or larvae inhabit the upper water strata but descend as they mature.

Some arctic marine fishes occur in large numbers locally in summer and provide a food supply for other fishes, birds, mammals, and man. Large concentrations of shoaling species are a primary food source for sea cliff birds. Birds in the Cape Thompson area alone have been estimated to consume 13,100 metric tons of fish during a single breeding season. The primary food item, Arctic cod, is consumed at a calculated rate of 190,000 fish per day for a total of 2.5×10^8 per season. Other rookeries along the Arctic coast undoubtedly contain similar ravenous bird populations dependent upon fish stocks.

B. Wildlife Resources

1. Birds

Abundance, distribution and environmental needs of many of the Arctic birds are only poorly known. Approximately 171 bird species utilize the Alaskan north coast during the short Arctic summer. Fifty of these species can be found along the shores of the Beaufort Sea. Offshore areas are used for feeding, while estuaries and nearshore uplands are used for reproduction. Estimates exceeding 11 million birds have been made for migrants arriving from such diverse locations as South America, Asia, Africa, and even Antarctica.

Certain areas along the coast are keyed to individual avian activities. The Snow Goose, for instance, utilizes an area near Prudhoe Bay for breeding, then moves west to the coastal area near the Ikpikpuk River for molting, only to return east to the Arctic Wildlife Range for staging prior to the fall migration south.

To the west, an area of approximately 65,000 acres in the vicinity of Cape Lisburne has been proposed as the Chukchi Sea National Wildlife Refuge to protect and accommodate some 2 million seabirds and their specialized habitat.

The bird resources of the Arctic have been used as a staple food and clothing source by Arctic native peoples for centuries. Severe disruption of the bird populations could result in a concomitant adverse impact on the subsistence life style of the native people.

2. Marine Mammals

Most of the marine mammal species that occur in Alaskan waters are seasonal entrants and range primarily in international waters. Consequently, they are of concern and potential value not only to the United States but to several nations. Marine mammals were a dominant element in the evolution of the Eskimo culture and, in some Native communities, they still remain as important sources of food, clothing and cash income.

Probably the most spectacular of the marine mammals associated with the Arctic coast is the polar bear. This large carnivore has a circumpolar range and can be found as far south as St. Matthew and St. Lawrence Islands. In winter, these animals are common throughout the drifting ice zone and occasionally visit the shorefast ice and beach regions. Denning takes place on offshore islands, to the outer edge of the shorefast ice pack, and up to 25 miles inland, particularly the area from the mouth of the Colville River east to the mouth of the Canning River.

C. Unique and Highly Productive Areas

1. Refuges and Management Areas

Two National Wildlife Refuges are located in this region: The Arctic, encompassing 8.9 million acres in the northeast corner of Alaska fronting on the Arctic Ocean and Chamisso, consisting of Chamisso Island, Puffin Island and adjacent islets in Kotzebue Sound. The Arctic National Wildlife Refuge is inhabited by a number of mammal species, including polar bear, and also supports migratory waterfowl and shorebirds. Chamisso is one of the most important breeding areas for Arctic sea birds on the northwest coast of Alaska.

D. Endangered and Threatened Fish and Wildlife. A threatened species is an animal species threatened with extinction within the foreseeable future but for which the Secretary of the Interior has not, as yet officially declared (via the Federal Register) to be an endangered species (U.S.D.I., 1973).

An endangered species is an animal declared by the Secretary of the Interior to be in danger of extinction throughout all or a significant portion of their range. Such an animal is named on the official Endangered Species list (U.S.D.I., 1973).

Tables __A__, __B__, __C__, and __D__ list the endangered and threatened species which occur along the Atlantic, Gulf of Mexico, Pacific and Alaska coasts, respectively. The tables also list the status, distribution, and suspected cause for their designated status. A species whose status is endangered is designated by an E; those threatened are designated by a T.

Table A.

THREATENED AND ENDANGERED SPECIES THAT OCCUR IN THE ATLANTIC COASTAL AREAS

COMMON NAME	SCIENTIFIC NAME	STATUS	PRESENT DISTRIBUTION	CAUSE FOR STATUS
Shortnosed sturgeon	Acipenser brevirostrum	E	Hudson River & Florida	Pollution
Blueback trout	Salvelinus alpinus oquassa	T	Maine	Overfishing
Roanoke bass	Ambloplites cavifrous	T	North Carolina and Virginia	Damming and siltation
Suwannee bass	Micropterus notius	T	Florida	Not known
Maryland darter	Etheostoma sellare	E	Maryland	Not known
Trispot darter	Etheostoma trisella	T	Alabama and Georgia	Artificial flooding of habitat
American croccodile	Crocodylus acutus	T	South Florida	Hunting, Destruction of habitat
American alligator	Alligator mississippiensis	E	North Carolina South	Hunting and Destruction of habitat
Eastern brown pelican	Pelecanus occidentalis carolinensis	T	North Carolina to Texas	Pesticide pollution
Florida great white heron	Arder o. occidentalis	T	Biscayne Bay to Cape Romano	Storms, Hunting
Florida everglade kite	Rosthrhamus sociabilis plumbeus	E	Central and South Florida	Hunting, destruction of habitat
Southern bald eagle	Haliaeetus l. leucocephalus	T	New Jersey to Texas	Destruction of habitat, Hunting
Eskimo curlew	Numenius borealis	T	New Jersey & South Carolina	Not known
Red-cockaded woodpecker	Dendrocopos borcalis	E	Virginia-South	Habitat destruction
American ivory-billed woodpecker	Campehilus p. principalis	E	Texas and Louisiana	Habitat destruction and hunting
Bachman's warbler	Vermivora bachmanii	T	Virginia and South Carolina	Habitat destruction
Ipswich sparrow	Passerculus princeps	T	Atlantic Coast	Habitat destruction
Dusky seaside sparrow	Ammospiza migrescens	E	Florida	Habitat destruction

Table A , cont.

ATLANTIC (cont')

COMMON NAME	SCIENTIFIC NAME	STATUS	PRESENT DISTRIBUTION	CAUSE FOR STATUS
Cape sable sparrow	Ammospiza mirabilis	E	Florida	Habitat destruction
Delmarva peninsula fox squirrel	Sciurus tiger cinereus	E	Maryland	Habitat destruction
Everglades fox squirrel	Scirius niger avicennia	T	Southwest Florida	Habitat destruction
Key Largo woodrat	Neotoma floridana smalli	T	Florida	Habitat destruction
Block Island meadow vole	Microtus pennsylvanicus provectus	T	Rhode Island	Habitat destruction
Beach meadow vole	Microtus breweri	T	Massachusetts	Predation, Habitat destr.
Sperm whale	Physeter catodon	E	Atlantic Coast	Hunting
Blue whale	Balaenoptera musculus	E	Atlantic Coast	Hunting
Finback whale	Balaenoptera physalus	E	Atlantic Coast	Hunting
Sei whale	Balaenoptera borealis	E	Atlantic Coast	Hunting
Humpback whale	Megaptera novaeangliae	E	Atlantic Coast	Hunting
Right whale	Eubalaena gracilis	E	Atlantic Coast	Hunting
Bowhead whale	Balaena mysticetus	T	N. Atlantic Coast	Hunting
Florida panther	Felis concolor coryi	E	Florida and Georgia	Hunting, Trapping, habitat destruction
Eastern cougar	Felis concolor cougar	E	Atlantic Coast	Hunting, Trapping, habitat destruction
Caribbean monk seal	Monachus tropicalis	E	Florida	Hunting
Florida manatee	Trichechus manatus latirostrus	E	Florida	Habitat destruction

Atlantic Ridley turtle Hawksbill turtle Leatherback turtle	see Gulf of Mexico section following

Table B.

Gulf of Mexico

Common Name	Scientific Name	Status	Distribution	Cause for Status
Okaloosa darter	Etheostoma okaloosoe	E	Florida	Man induced siltation
Tuscumbia darter	Etheostoma trisella	T	Alabama	Man induced flooding
Pygmy sculpin	Cottus pygmaeus	T	Alabama	Pollution
American crocodile	Crocodylus acutus	T	South Florida	Hunting, destruction of habitat
American alligator	Alligator mississippiensis	E	South Fla. to Corpus Christi Texas	Hunting and habitat destruction
Eastern brown pelican	Pelecanus occidentalis carolinensis	E	N.C. to Texas	Pesticide pollution
Florida great white heron	Aroea o. occidentalis	E	Biscayne Bay to Cape Romano	Storms, hunting
Southern bald eagle	Haliaeetus l. levcocepnalus	E	N.J. to Texas	Habitat destruction, hunting
Arctic peregrine falcon	Falco peregrinus tundrius	E	Gulf Coast	Pesticide pollution
Mississippi sandhill crane	Grus canrdensis pulla	E	Mississippi	Destruction of habitat
Red-cockaded woodpecker	Dendrocopos borcalis	E	Gulf Coast	Destruction of habitat
American ivory-billed woodpecker	Campehilus principalis	E	Texas and Louisiana	Destruction of habitat, hunting

222.

Table B , cont.

Gulf of Mexico

Common Name	Scientific Name	Status	Distribution	Cause for Status
Bachman's warbler	*Vermivora bachmani*	E	Alabama	Habitat destruction
Red wolf	*Canis rufus*	E	Texas and Louisiana	Hunting, trapping, habitat destruction
Florida panther	*Felis concolor coryi*	E	Florida	Hunting, trapping, habitat destruction
Florida manatee	*Trichechus manatus latrirostris*	E	Florida	Hunting, habitat destruction
Key deer	*Odocoileus virginianus clavium*	E	Florida	Habitat destruction
Atlantic Ridley turtle	*Lepidochelys kempii*	E	South Atlantic; Gulf of Mexico	1/
Hawksbill turtle	*Eretmochelys imbricata*	E	Tropical Seas	1/
Leatherback turtle	*Dermochelys ceriacea*	E	Tropical and Temperate Seas	1/

Overexploitation and nesting habitat loss.

Table C

Endangered and threatened wildlife species that occur in coastal regions of California, Oregon, and Washington

Common Name	Scientific Name	Status	Distribution	Reason for Status
Olympic mudminnow	*Novumbra hubbsi*	T	Olympic Penin., Wash.	Habitat change
Santa Cruz long-toed salamander	*Ambystoma macrodactylum croceum*	T	Santa Cruz, Calif.	Land development; subdivisions
San Francisco garter snake	*Thamnophis sirtalis tetrataenia*	E	San Francisco, Calif.	Land development; vegetation removal
California brown pelican	*Pelecanus occidentalis californicus*	T	Southern Calif.	Poor reproduction due thin egg shells
Tule white-fronted goose	*Anser albifrons gambelli*	T	Central Calif., north to Wash.	Small popn., vuln. to hunting
California condor	*Gymnogyps californianus*	E	Central and So. Calif.	Disturbance by man
American peregrine falcon	*Falco perigrinus anatum*	T	Calif. to Alaska	Poor reproduction and adult survival
California clapper rail	*Rallus longirostris absoletus*	T	San Francisco Bay, Calif.	Habitat reduction
Light-footed clapper rail	*Rallus longirostris levipes*	T	Southern Calif.	Habitat destruction
California black rail	*Laterallus jamaicensis coturniculus*	T	Central Calif.	Habitat reduction

Table C, (Cont.)

Common Name	Scientific Name	Status	Distribution	Reason for Status
California least tern	*Sterna albifrons*	T	Central to Southern Calif.	Habitat reduction
Spotted owl	*Stirix occidentalis*	T	Calif. to Wash.	Habitat removal
Santa Barbara sparrow	*Melospiza melodia graminea*	E		
Morro Bay kangaroo rat	*Dipodomys heermanni morroensis*	E	Morro Bay, Calif	Habitat destruction, predation by cats
Salt marsh harvest mouse	*Reithrodontomys raviventris*	E	San Francisco, Calif.	Habitat destruction
Sperm whale	*Physeter catodon*	E	Pacific Coast	Over-exploitation
Gray whale	*Eschrichtius robustus*	E	"	"
Blue whale	*Balaenoptera musculus*	E	"	"
Finback whale	*Balaenoptera physalus*	E	"	"
Sei whale	*Balaenoptera borealis*	E	"	"
Humpback whale	*Megaptera novaeangliae*	E	"	"
Right whale	*Eubalaena glacialis*	E	"	"
Guadalupe fur seal	*Arctocephalus philippi townsendi*	E	Santa Barbara Channel Islands, Calif.	Small population

Table D .

Endangered and threatened wildlife species that occur in coastal regions of Alaska.

Common Name	Scientific Name	Status	Distribution	Reason for Status
Aleutian Canada Goose	Branta canadensis leucopareia	E	Aleutian Islands, Western U.S.	Predation by Arctic foxes and rats.
Short-tailed Albatross	Diomedea albatrus	E	Gulf of Alaska	Excessive hunting for feathers
Eskimo Curlew	Numenius borealis	E	Formerly N.E. Alaska Now U.S. east coast	Excessive hunting
Arctic Peregrine Falcon	Falco peregrinus tundrius	E	Arctic Alaska, eastern and Middle No. Amer.	Population decline, due to pesticides (suspected).
American Peregrine Falcon	F.p. anatum	E	Non-Arctic Alaska to Baja California	As above
Sperm Whale	Physeter catodon	E	Pacific Ocean	Over-exploitation
Gray Whale	Eschrichtius robustus	E	"	"
Blue Whale	Balaenoptera musculus	E	"	"
Fin Whale	Falaenoptera physalus	E	"	"
Sei Whale	Balaenoptera borealis	E	"	"
Humpback Whale	Megaptera novaenagliae	E	"	"
Black Right Whale	Balacna glacialis	E	"	"
Bowhead Whale	Balaena mysticetus	E	"	"
Glacier Bear	Ursus americanus emmonsii	T	Glaciated Alaska, esp. near Yakutat	Over-exploitation